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Preliminary Design of a Ventilation System Scrubber To Reduce Sulfur Dioxide Emissions at the Watervliet Arsenal Industrial Wastewater Treatment Plant

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Foreword

This research was funded under 622720960, “Congressional – Watervliet Arsenal Pollution Projects.” The project was co-developed under the Value Engineering Program of the U.S. Army Corps of Engineers. The project described in this report was conducted at Watervliet Arsenal (WVA) during Fiscal Year 2001. The technical monitor at WVA was Dan Brown.

The work was performed by the Environmental Processes Branch (CN-E), Installations Division (CN), Construction Engineering Research Laboratory (CERL), and by consultants MSE Technology Applications, Inc. (MSE-TA), Butte, MT. The principal investigator was Joyce C. Baird, CERL, Champaign, IL, and June Pusich-Lester was project manager for MSE services. Michelle Hanson is Acting Branch Chief, CN-E, and Dr. John Bandy is Chief, CN. The technical editor was Linda L. Wheatley, Information Technology Laboratory—Champaign. The associated CERL Technical Director was Gary W. Schanche. The Director of CERL is Dr. Alan W. Moore.

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1 Introduction

Background

The Industrial Wastewater Treatment Plant (IWTP) (Figure 1) was built in the early 1960s at Watervliet Arsenal (WVA) in New York, and the chrome plating wastewater treatment control system was upgraded in the early 1980s. This control system upgrade did not include consideration of emissions from ventilation of the reaction tanks or clarifiers.



Figure 1. Industrial Wastewater Treatment Plant at WVA.

http://www.globalsecurity.org/military/library/report/enviro/WVA_IAP.pdf

WVA has a large hexavalent chromium electroplating facility that generates chromic acid wastewater. WVA's IWTP treats the industrial wastewater and discharges it into the Hudson River. The current acid waste treatment process uses a large sulfur intake. Sulfuric acid (H_2SO_4) is added to the waste stream to lower the pH, sulfur dioxide (SO_2) is added to reduce the hexavalent chromium to trivalent chromium, and aluminum sulfate (alum) is used to aid in the precipitation of the trivalent chromium. Although the IWTP possesses a New York State air permit, the odor the plant generates has been a concern. The generation of

hydrogen sulfide (H_2S) or the addition of excess SO_2 to the acid waste treatment process may cause the odors.

Present Situation at WVA's IWTP

The IWTP at WVA provides chrome plating wastewater and oily wastewater treatment for all waters produced during manufacturing at the WVA. All reaction tanks and clarifier tanks at the IWTP have polycarbonate covers. Fans were added to ventilate the air space between the process water and the tank covers. The ventilation fans exhaust from chimneys that extend above the roof of the IWTP.

The SO_2 used in the treatment of the chrome plating wastewater is injected into the process stream using a sulphonator system. The SO_2 tanks and sulphonator are in a room adjacent to the reaction tanks. Past concerns from operation personnel indicate that the IWTP process generates odors during chromic acid wastewater treatment. The odor has been variously attributed to the generation of H_2S or the addition of excess SO_2 to the acid waste treatment process.

Past Work Conducted at WVA's IWTP

The overall scope of this project had three parts. These parts included:

2. Implementing an investigation to determine the nature and cause of any sulfur emissions as well as determining potential solutions,
3. Development of a chosen solution method, and
4. Implementing the chosen method.

The scope of the work reported here addressed part two by developing a method to solve the problem.

Dr. James Hay of CERL completed part one of the project in 1996. Results of Dr. Hay's Experiment #1 performed on 11 December 1995 at WVA's IWTP indicated no H_2S from any of the emission points. Researchers did record measurements of SO_2 emissions. These results were puzzling as workers stated that H_2S odors should be present when the plant was started up after a weekend and higher SO_2 concentrations were expected.

Researchers performed Experiment #2 on 28 February 1996. This two-part experiment included tests for SO_2 emissions from reaction tank #2 and biological samples from several points in the process. Results from the biological samples

showed that sulfate reducing bacteria (SRB) were present at all locations from where samples were taken and that conditions were conducive to SRB growth. Although researchers did not detect any H₂S emissions during experiments, it was suspected that the gas was present during the warmer months of the year. This suspicion was based on worker testimony and the confirmed presence of SRB. The second experiment also showed that, under conditions of high chromium concentration influent to the acid waste treatment process, a relatively strong concentration of SO₂ emissions could be vented to the atmosphere. The Hay's report suggested a number of solutions to the H₂S problem including: operational modifications; treatment of SRB; removal of food source; or a combination of the above options. The full results of Dr. Hay's work are included as Appendix A.

Site Investigation

MSE Technology Applications, Inc. (MSE-TA) and WVA personnel conducted a site survey in August 2001. During the 2001 survey, MSE personnel toured the IWTP, discussed real-time operation of the plant with operations personnel, and documented operating streams such as emission point locations, stack locations, and stack diameter and height. At a later visit, MSE personnel examined and proposed piping routes and equipment locations. From the survey, and at a subsequent meeting of all parties involved, MSE and WVA decided to consider several options for the design of a system to reduce emissions that cause nuisance odors.

The IWTP had at one time been used to treat wastewaters containing cyanide from the plating process. Because of environmental concerns, however, WVA no longer uses the cyanide treatment process. It was decided during the site visit that the cyanide treatment room would be available to house the proposed ventilation air treatment equipment.

Three designs for the process were developed. The first two were completed prior to solicitation of proposals from vendors. The third design was developed using vendor-provided information following solicitation. The first design used an SO₂ wet scrubber, absorber, and an H₂S adsorber. The second design eliminated the adsorber in favor of drawing all vent streams into a common header and using a wet scrubber for both SO₂ and H₂S absorption. The recommended design was developed from the second alternative design by adding specific manufacturer equipment operating parameters. The first option was to design a wet scrubber to remove SO₂ and an adsorber to remove H₂S from the ventilation air streams. The second option would incorporate H₂S scrubbing into the wet

scrubber design. As explained later in this report, the second option was found to be the best solution to mitigate the problem.

Objective

The objective was to develop a design to eliminate emission of SO₂ and H₂S from the chrome plating wastewater treatment process, which was causing nuisance odors at WVA's IWTP.

Approach

The approach to the project was to provide specifications for systems and components to absorb or adsorb SO₂ and H₂S from the ventilation air effluent streams at the IWTP.

Mode of Technology Transfer

It is anticipated that this report and accompanying documentation will be available on the CERL and WVA Intranet web pages.

The CERL web site address is: <http://www.cecer.army.mil/>

The WVA web site address is: <http://www.wva.army.mil/>

Units of Weight and Measure

U.S. standard units of measure are used throughout this report. A table of conversion factors for Standard International (SI) units is provided below.

SI conversion factors		
1 in.	=	2.54 cm
1 ft	=	0.305 m
1 gal	=	3.78 L
1 lb	=	0.453 kg

2 Process Analysis of Multiple Technologies

The IWTP Waste Treatment Processes

The purpose of the IWTP at WVA is to clean and rejuvenate the water used in the machining process. The IWTP originally had three treatment processes: acid, cyanide, and soluble oil. The yearly treatment rates for the acid treatment line, the cyanide treatment line, and the soluble oil line were, respectively, 25,000,000 gallons per year, 17,000 gallons per year, and 5,000,000 gallons per year (1996). Figure 2 is a flowchart of the three original treatment processes. Due to environmental concerns, WVA no longer uses cyanide treatment.

The Acid Treatment Line

The acid waste process treats the hexavalent chromium waste generated by the large chromium electroplating operations at WVA. The concept is to precipitate out the chromium for disposal in the less toxic trivalent state. Wastes from the electroplating operations are usually directed towards the acid receiving well or to either of two storage tanks (75,000 and 39,000 gallon capacities) to be processed. The process influent is treated with H_2SO_4 to reduce the pH to about 2.5. There are two treatment lines with flow capacities of 120 gallons per minute (gpm). For each process line, pressurized SO_2 is injected into the process stream to reduce hexavalent chromium to trivalent chromium. The sulfonated influent flows into a reaction tank where reduction is completed and then treated with sodium hydroxide (NaOH) to raise the pH to about 8. The addition of NaOH initiates the production of the trivalent chromium precipitate. The stream is then directed towards a blending tank where alum is added. The flow is then pumped to one of two clarifiers where polyelectrolyte is added to enhance settling of the precipitate. Sludge forms on the bottom of the clarifiers and is periodically transferred to drying beds. The “clean water” effluent from the clarifiers is discharged to the river.

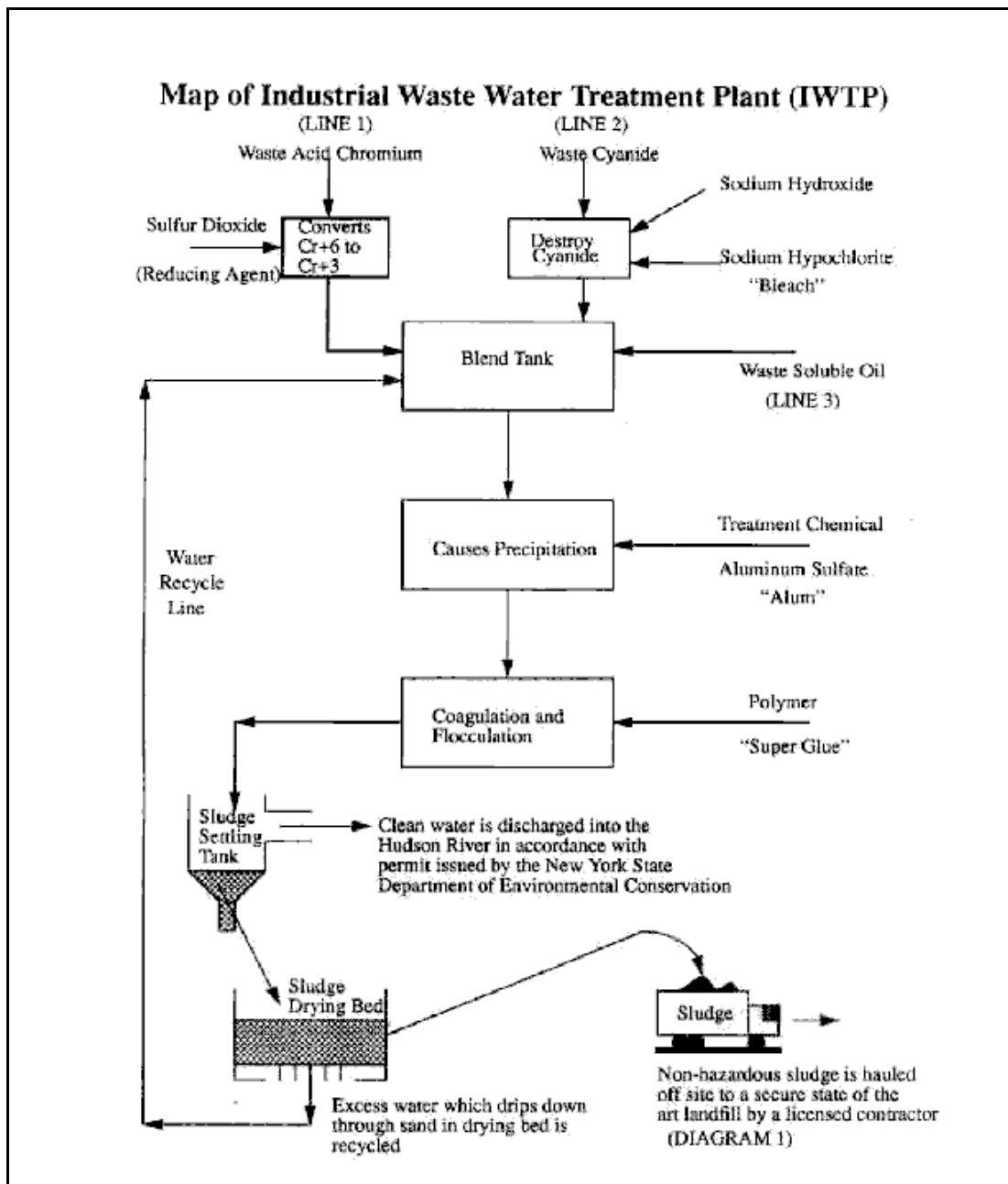


Figure 2. WVA's three IWTP treatment processes (1995).

<http://www.rpi.edu/dept/chem-eng/Biotech-Environ/TreatmentPlants/Arsenal/FLOW1>

The Soluble Oil Treatment Line

The soluble oil treatment process is a batch process with two 6,700-gallon batch tanks with a treatment rate anywhere from one to six batches per day. More treatments appear to be warranted during the fall and spring due to more rainfall. The batch tanks slowly fill with influent; once full they are treated immediately. Treatment consists of adding H_2SO_4 and alum to lower the pH to 4 or 5 and to disperse the oil emulsion; adding NaOH to raise the pH to 8; adding

polyelectrolyte to generate precipitate; allowing the sludge to settle for 30 to 60 minutes; and removing the batch contents. The last step includes removing the combustible skim oil off the top to a holding tank, conveying the sludge to the drying beds, and directing the noncombustible soluble oil waste effluent to the acid waste receiving well. The batch process from the addition of H_2SO_4 usually takes no more than 2 hours. The effluent from the soluble oil treatment process returns to the acid receiving well for a second treatment in the acid waste process.

The Cyanide Treatment Line

The waste cyanide line, when active, carried cyanide-laden rinse waters. The line carried the waste into a tank where it was destroyed by adding sodium hypochlorite and NaOH. This product then moved into a blend tank into which the line carrying the waste soluble oil also entered. The effluent from the cyanide treatment process returned to the acid receiving well for a second treatment in the acid waste process.

Criteria for Design Selection

The criteria for design selection of ventilation air SO_2 control for the WVA IWTP were developed from the *Air Pollution Management Study No. 42-EK-4457-96, U.S. Army Center for Health Promotion and Preventative Medicine* (Appendix A). This report included multiple studies conducted at the plant over the last 5 years. One study reported the flow rate and SO_2 concentration of the exhaust air from Reaction Tank Number 2 during chrome processing. The maximum concentration of SO_2 was 205 ppmv. The flow rate of air from the tank was 36,601 dscf/h. Another study indicated that an estimate of H_2S concentration to be between 2 – 5 ppmv.

The report *Air Emissions Inventory, Watervliet Arsenal, September 1997* contains additional information used as criteria for the design. This report is also provided in Appendix A. The report gave ventilation fan flow rates and SO_2 emission rates at point source locations at the IWTP. An estimate of H_2S concentration was also included in the report. Table 1 repeats the data from this report.

Table 1. Air emissions inventory report data.

Source	Description	Flow (acfm)	Concentration	
			SO ₂ (lb/h)	H ₂ S (ppmv)
26a	Reaction Tank 1	415	1.3	
26	Reaction Tank 2	608	1.3	
193	Blend Tank 2	300		2
194	Clarifiers	1,750		2
195	Oil Batch Tank	1,750		2
196	Sludge Tank	300		5
199	Blend Tank 1	300		2

The report *Sulfur Emissions at the Watervliet Arsenal Industrial Wastewater Treatment Plant* by Dr. Hay provided background on the project and insight into the operation of the IWTP. Although Dr. Hay's report states that no H₂S was detected during the course of experiments at the plant to determine emission quantities, the results shown in Table 1 from *Air Emissions Inventory, Watervliet Arsenal, September 1997* (see Appendix A) indicate that H₂S was present.

For the design concept presented in this report, the flow rates of vent air from each of the reaction tanks were chosen to be 624 actual cubic feet per minute (acfm) with an SO₂ concentration of 225 parts per million volume (ppmv). For the balance of the equipment from the plant, the vent flows and H₂S concentrations were set to the values from the cited air emissions inventory report.

Description of Designs for the Process

Three designs for the process were developed. The first two were completed prior to solicitation of proposals from vendors. The third design was developed using vendor-provided information following solicitation. The first alternative design was completed before the MSE site visit.

First Alternative Design

Drawing E17-36FS-001 (Appendix G) depicts a simplified process flow diagram (PFD) of the IWTP. The proposed pollution control equipment for SO₂ scrubbing and H₂S adsorption is shown on the PFD. The operation of the proposed equipment is described below.

Sulfur dioxide wet scrubber (absorber)

Due to phase equilibrium, a partial pressure of SO_2 will always be in the head-space of the reaction tanks. From the documents inspected while developing the design, it appears that SO_2 emission fluctuates in the vent gas from the reaction tanks because SO_2 concentrations exceed what is necessary for the chromate reduction reaction. This was just a supposition, however, since no information had been supplied that stated the concentration requirements for the reduction reaction. In addition, there was no evidence that the emission of SO_2 exceeded any air-permit limitation.

To remove the SO_2 from the vent gas, using a packed column scrubber (equipment list item A) was proposed. Aqueous NaOH would be used to absorb and neutralize the SO_2 . Since the concentration of SO_2 is low in the vent gas, the quantity of caustic required is also low.

As shown in the PFD, the vent gas from the two reaction tanks (streams 26a and 26b) are combined and are drawn into the bottom of the scrubber by the induced draft fan (item C). The combined gas stream, at approximately 92.4 pounds per minute (approximately 1,248 acfm), flows upward in the tower's packing and is counter-currently contacted by recycled scrubber liquor. The scrubber liquor flows into a sump at the bottom of the tower and is recycled to the top. The level of the liquor in the sump is controlled by blowing down the excess through stream 36 to the blend tanks. If the sump level is low, additional clarifier overflow water can be added through stream 38.

NaOH is used as a reagent for SO_2 absorption and to maintain the pH of the scrubber at about 8. The quantity of caustic shown on the PFD is minimal; the system will be designed to inject at least 10 times the required amount to allow for fluctuations in SO_2 concentration, and to allow rapid pH adjustment.

The level of scrubber liquor in its sump controls blows down from the absorber. The blow-down quantity shown is essentially the water coming into the system with the aqueous caustic. Since Watervliet is a humid location, the quantity of scrubber blow-down will increase from that shown in the PFD, especially in the summer. In the winter, make-up should be added at approximately the same rate as the caustic to keep the total dissolved solids (TDS) concentration in the liquor relatively low.

Blow-down reports to the blend tanks through stream 36. By rejecting blow-down to the blend tanks, installation of the scrubber will not increase plant waste streams. The blow-down quantity is sufficiently low and should not have

an effect on the action of the blend tanks, especially since it will consist of the same components entering the blend tanks from the reaction tanks.

Absorber equipment design

A performance specification was written for the SO₂ scrubber and sent as a Request for Quotation (RFQ). There are many scrubbing equipment vendors on the market who have built competitive equipment. Typically, a scrubber such as the one proposed for the IWTP would be made of fiber-glass reinforced plastic (FRP) and would require weatherization to prevent freezing (unless it is installed inside a building).

A preliminary sizing of a typical SO₂ scrubber had been made based on the information shown in the PFD. The packed bed scrubber would be in the range of 30 to 36 inches in diameter. The height of the packing in the scrubber would be between 4 to 6 feet and the overall height would be between 12 to 15 feet. The scrubber was designed at a liquid to gas ratio of about 10 gpm of liquor to 1,000 acfm of inlet gas; this ratio is a minimum for good wetting of the packing, and may need to be increased to 20 gpm/acfm in a final design.

Vendors' designs may vary from the above because of operating experience and proprietary information. This application is nontypical due to the low inlet concentration of SO₂.

Hydrogen sulfide adsorption

The proposed control for H₂S is the commercial adsorbent process "SulfaTreat." Information on the process is available from the company's Web site (<http://www.sulfatreat.com>); information from that site is abstracted below.

The SulfaTreat process is a fixed bed or batch type granular hydrogen sulfide reactant consistent in shape and size contained in a pressure vessel. The starting material and spent product are safe and stable. Gas or vapor flows through the granular product in the bed chemically reacting with hydrogen sulfide forming a stable and safe byproduct. Consumption of the SulfaTreat product is only dependent on the amount of hydrogen sulfide that passes through the bed economically matching the need for H₂S removal with variations in system flow conditions and outlet specification regardless of the total volume or other common components of the gas. Computer assisted vessel design specifications are based on highest gas flow rates, minimum operating temperature, inlet H₂S content and

maximum outlet specification, minimum operating pressure and allowable pressure drop, water content of the gas, and convenient operation. Flexibility of this process allows the system to adapt to variations in H₂S outlet specifications that may result from changes in operating preferences or tighter regulations often without additional capital equipment or system retrofitting. Predictable pressure drops, long bed life, easy and safe to handle, and a simple reliable operation are a few of the features of the SulfaTreat process.

The output of the ventilation fans from the blend tanks, the clarifiers, the oil batch tanks, and the sludge tank (equipment items E, F, G, and H) will be combined and will report to a set of parallel SulfaTreat reactors (item K). The flows from the fans are assisted by the adsorber-induced draft fan (item L). Since the concentration of H₂S is reportedly low, the size of the reactors will be minimal and operation long-term. Depletion of each reactor is indicated by H₂S breakthrough at the exit of the reactor.

Adsorber equipment design

The best description of the required equipment is available on the company's Internet site, as mentioned above.

Second Alternative Design

After evaluation of the first design, a second design was developed to eliminate the Sulfa-Treat adsorbers in favor of drawing all vent streams into a common header and using a wet scrubber for both SO₂ and H₂S absorption. The resulting design is depicted in PFD E17-36FS-002 (Appendix G) and a ChemCad model of the scrubber is included in Appendix B.

For this alternative design, a wet scrubber was considered that used only clarifier water to scrub the SO₂; no NaOH (caustic) was added. It was found that using water alone to scrub the vent streams would remove only about 8 percent of the SO₂ and no H₂S. It was concluded, therefore, that caustic would be needed to ensure complete scrubbing of the vent streams.

The flow sheet E17-36FS-002 depicts the system using caustic to effect scrubbing of SO₂ and H₂S. The operational description of the process is similar to that of the first alternative. Initial absorber equipment design estimated a larger diameter absorber, at about 42 inches inside diameter, and a packing depth of nearly 12 feet of 2-inch pall rings. This design was used as a basis for developing the performance specification that was sent out for quotation. It was felt that

commercial suppliers would propose a similar absorber that may be shorter if based on operational experience.

An equipment data sheet was developed that outlines the operating conditions, system components, construction materials, unit performance, controls, and equipment warranty. This data sheet (Appendix C) was developed using results of the ChemCad model and prior experience in designing and selecting packed column scrubbers.

Recommended Design

Drawing E17-36FS-003 (Appendix G) depicts the design recommended by MSE and proposed by the Duall Division of Met Pro Corporation. The flow sheet depicts the operating parameters and inlet concentrations from the performance specification that were to be used for design.

Met Pro proposed a 45-inch-diameter scrubber with 5 feet of 2-inch polypropylene packing. The system can remove better than 94 percent of the SO₂ and more than 60 percent of the H₂S from the combined vent stream. The makeup water rate from the clarifier is higher than that estimated from the second alternative flow sheet. The higher water rate may be caused by the need to keep ionic strength or TDS concentration low. The blow-down water is higher as a consequence. Since the make-up water is from the clarifier, and the blow-down water reports back to the acid receiving well, there is no net use or disposal of water from the scrubbing system. Some water losses will occur due to evaporation, however.

The Met Pro design uses a somewhat higher flow rate of caustic solution. The higher caustic usage is needed to keep the recycle liquor pH above 11, a level needed to effectively scrub H₂S without excessive make-up water requirements.

The Met Pro design depicts blow-down overflowing to a drain. Level in the sump of the scrubber is controlled by make-up water flow. Drawing E17-36FS-003 (Appendix G) depicts the overflow water draining to an existing building sump from where it is pumped or drained to the acid receiving well. If the building sump cannot be used for this purpose, a pump would need to be added to accomplish transport of the blow-down to the well.

3 Vendor Quotations

A list of vendors was developed and an RFQ was sent to the equipment providers. The three sources selected to receive an RFQ are shown in Table 2. The vendors were asked to submit a quote within 21 days of receipt of the technical proposal. Two companies responded with a quote, and one of the companies, Met-Pro Corporation Duall Division, provided equipment drawings with their quote. The vendor quotes received are included in Appendixes D and E.

Review of the two vendor quotes revealed a large cost differential between the proposed equipment. This difference can be attributed to the following factors:

- Met-Pro Corporation Duall Division produces an off-the-shelf item.
- Rocky Mountain Process Group (RMPG) manufactures custom-built equipment and provides engineering design services with all contracts. The scope of work from RMPG also included extensive engineering review, operator training, start-up assistance, and documentation, which were not required.

Table 2. Vendor sources.

Vendor Name	Address/Phone
CAMTEC Industrial Sales	P.O. Box 1700 Sandy, UT 84091 (801) 566-6000
Rocky Mountain Process Group	872 Don Cubero Avenue Santa Fe, NM 87501 (505) 983-1661
Process Combustion Corporation	5460 Horning Road Pittsburgh, PA 15236 (412) 655-0955
Met-Pro Corporation Duall Division	1550 Industrial Drive Owosso, MI 48867 (989) 725-8184

4 Recommendations

Based on the lower cost of the Met-Pro Corporation Duall Division equipment, a preliminary design and a cost estimate were developed using the equipment indicated in Appendix E. A ChemCad model of the scrubber conforming to the specification operating parameters is included in Appendix F.

Equipment Description

The Met-Pro Corporation Duall Division equipment uses a single stage packed tower scrubber with an integral exhaust fan. Additional equipment includes a chemical feed pumping system, instrumentation to operate and monitor the process, and a control panel that contains a supply power, parameter indication, alarms, controls, and process interlocks.

Additional costs associated with the equipment but not included in the base price estimate:

- installation of packing into tower,
- connection of control panel to existing plant controls and alarms,
- electrical wiring, motor control centers, local disconnects, instrumentation and connection accessories,
- chemicals,
- additional piping, valves, and accessories required for connection to the IWTP,
- installation, start-up, balancing, and training services, and
- performance testing and scheduled system inspections.

Plan Views of Equipment Installation

Installation of the equipment in the cyanide room at the IWTP is indicated in Drawing No. EE17-36GA-001 (Appendix G). As shown in the drawing, the equipment can be located inside the building with the exception of the exhaust stack exiting through the roof.

Site Preparation Requirements

To use the cyanide room, existing process equipment will need to be removed and disposed of according to facility disposal methods. Additionally, some modification of the building structure will need to be completed prior to the equipment installation. The installation of a door opening of at least 8 feet needs to be added to the room. Also, a crane capable of lifting at least 1,500 pounds is required temporarily.

A partial listing of the existing equipment that requires removal prior to installation includes:

- two cyanide wastewater storage tanks,
- one instrumentation panel,
- two cyanide wastewater pumps,
- miscellaneous piping and grating, and
- associated instruments and alarm signals.

Electrical Requirements

Additional plant electrical utilities required to install and maintain the unit include:

- 460 volt/3 phase/60 Hertz power,
- 120 volt/1 phase/60 Hertz power, and
- pump motor start circuits.

Piping and Mechanical Requirements

The design of the system requires water and aqueous NaOH be added to the system to perform the necessary scrubbing. Additionally, a unit drain line is required to circulate the spent water back through the chromic acid wastewater treatment process. The main advantage of using the proposed system is the use of the existing plant-clarifier water for the process water supply and the ability to add the spent water back into the process.

The process piping requirements are:

- one Plant Service Water (PSW) supply line for cleaning of equipment,
- one water supply line from the two plant clarifier units,
- one unit drain line that runs from the unit to the IWTP intake sump,
- one drain line pump (if required),

- one clarifier supply pump, and
- one NaOH injection pump (supplied by Duall).

The exhaust from the scrubber will be vented to the outside atmosphere through the roof of the IWTP. This will require a stack to be installed that runs from the exhaust line of the equipment through the roof and extends approximately 10 feet above the roof in a similar manner as the existing vents. Additionally, the ventilation air from the process equipment has to be brought to a common header into the proposed equipment.

After installation of the equipment on the basement floor of the facility (elevation 17.0 feet), new grating will need to be installed on the ground floor at elevation 34.0 feet (above the proposed equipment).

Instrumentation Requirements

The proposed system is capable of operating using local controls. A local control panel contains the instruments shown in Appendix E. To ensure the proposed equipment is operating properly, all operating parameters should be tied into the IWTP alarm system and Line One Control Panel. This will allow operations personnel to monitor the status of the equipment, and will provide an audible alarm if a problem occurs during operation.

Operating and Maintenance Requirements

The operating and maintenance requirements for the proposed scrubber system are:

- replenishment of caustic solution,
- inspection and replacement of the polypropylene packing,
- inspection and maintenance of the spray header piping,
- inspection and maintenance of the caustic pumping system,
- inspection and maintenance of the drain piping, and
- inspection and maintenance of the exhaust fan and exhaust stack.

5 Cost Worksheets

A cost analysis of the recommended design is shown in Table 3. Key points of the cost analysis are as follows.

- The Met-Pro quote was used as the basis for the estimated costs. The cost analysis was performed using itemized costs and age factors. The age factors were added to the quote based on estimating techniques outlined in *Basic Cost Engineering; Third Edition, Revised and Expanded*, Humphreys and Wellman (1996).
- A 10-year net present value of cost was used in the estimate with a nominal 5.4 percent interest rate.
- Labor rates were estimated at \$45 per hour for operations.
- The NaOH supply will come from the existing plant supply at a value of \$1.00 per gallon.

Table 3. Cost estimate for installation and operation of scrubber system.

		Itemized			Estimate Using Humphreys and Wellman (5)			Notes
	Item	Material	Labor	Total	Material Factor	Labor Factor	Total (Estimated)	
Site Preparation								
1	Install 8' x 8' Industrial Rollup door	\$2,000	(See 11)	\$2,000			\$1,300	1
2	Rental of Crane and Operator	\$1,500	\$2,000	\$3,500			\$3,500	2
3	Removal of existing process equipment, wiring, and piping	None	(See 11)					
Scrubber Installation			(See 11)					
4	Scrubber, including shipping	\$34,800	(See 11)	\$34,800	0%	48%	\$51,500	6
5	Polypropylene Packing	Supplied	(See 11)					
6	Control Panel	Supplied	(See 11)					
7	Motor Control Center (MCC)	\$2,200	(See 11)	\$2,200	0%	40%	\$3,080	
8	Starters for MCC, 2 @ \$1,200 ea	\$2,400	(See 11)	\$2,400	0%	40%	\$3,360	
9	Misc. wiring	\$500	(See 11)	\$500	6%	40%	\$2,923	3
10	Plumbing	\$500	(See 11)	\$500	40%	50%	\$20,880	3
11	Labor		\$23,100	\$23,100		40%	\$13,920	4
12	Subtotals	\$43,900	\$25,100	\$69,000			\$100,463	
13	Contingencies @ 15%	\$6,585	\$3,765	\$10,350			\$15,069	
Installation Totals		\$50,485	\$28,865	\$79,350			\$115,532	7

		Itemized			Estimate Using Humphreys and Wellman (5)			Notes
	Item	Material	Labor	Total	Material Factor	Labor Factor	Total (Estimated)	
	Yearly Operational Costs							8
14	Caustic (0.1 gpm of 20% NaOH)	\$19,400						9
15	Electricity (at \$0.15 per kWh)	\$8,500						10
16	Labor at \$45 per hour.	\$19,400						11
17	Maintenance at 10%	\$10,000						12
18	Total	\$57,300						
	10 yr Net Present Value of Cost							
19	Averaged Estimated Installed cost	\$100,000						12
20	Net Present Value of Yearly Operating Costs, 10 years, 5.4%	\$434,000						13
21	Net Present Cost	\$534,000						

Notes:

1. Door cost is supplier's installed cost. Based on two quotes from local suppliers. Opening and frame to be completed by crew, and included in labor cost. Framework steel included in contingency, if not available from site.
2. May require a certified operator. May be furnished by Crane Renter. Average cost for a small CarryBack crane is \$1,000 per week, northwest prices. Weight of this crane is 7 tons. Rated 6 tons lift. Should try to find smaller, lighter unit. Average mobilization/demobilization is \$500 for 300 miles. Average operator cost is \$50 per hour, loaded. Estimated time required for crane and operator, 1 week.
3. Miscellaneous wiring estimated at \$500. Based on 200 feet ¾-inch galvanized piping and miscellaneous valves.
4. Based on a crew of one I&C technician, two electricians, two technicians qualified for mechanical, plumbing, and welding, all at \$45 per hour, one supervisor at \$60 per hour, and one engineer for 4 hours at \$80 per hour to verify bearing load on floor for crane. All rates loaded. Crew on site 2 weeks. Crew will cut and frame hole for door, remove old equipment, piping, electrical, install scrubber, control panel, MCC, wiring and plumbing, load scrubber, install stack in roof, train operators. Total labor cost \$23,100.
5. *Basic Cost Engineering*, 3rd ed., Revised and Expanded, Kenneth Humphreys and Paul Wellman (Marcel Dekker, Inc., 270 Madison Ave., New York, 1996).
6. Met-Pro quote. Used as basis for estimated costs using age factors.
7. Estimated cost is 46 percent higher than detailed cost, which is within an order of magnitude as defined by Humphreys and Wellman (-30 percent to +50 percent).

8. Based on operating schedule of 15 hours per day, 18 days per month, two shifts. Yearly operation is thus 3,240 hours.
9. Source will be facility, where reported cost is \$1.00 per gallon.
10. Power considered only for 5 hp and 10 hp motors. Will be estimated at maximum output of 15 hp. Electrical draw is 17.4 kw. This will absorb other power requirements of system.
11. Based one technician inspecting system for 1 hour per shift.
12. Taken as 10 percent of average of installed cost estimates (\$100,000).
13. 10 years of operating costs discounted at nominal interest rate of 5.4 percent as per OMB Circ. 094, Appendix C, January 2001.

6 Conclusions

This preliminary design provides a basis for the development of a ventilation system scrubber at the IWTP. Key points developed during the design include:

- Use of the existing cyanide treatment room will allow the proposed equipment to be located inside the building and will reduce the cost of heating the equipment if it were located in the outside environment. Additionally, electrical power, plant service water, a building sump, and easy access to the plant control panel in the cyanide room will reduce the overall scope and cost of the project.
- Use of the reports *Air Pollution Management Study No. 42-EK-4457-96, U.S. Army Center for Health Promotion and Preventative Medicine* and *Air Emissions Inventory, Watervliet Arsenal, September 1997* for the basis of design for ventilation air SO₂ control eliminated the need to perform sampling at the site during the preliminary phase. Additionally, these reports verified that only a small amount, 2 – 5 ppmv, of H₂S gas is present in the process tanks. The use of a single process equipment technology, a wet-scrubber for both SO₂ and H₂S absorption, reduces the physical size and the cost of the treatment process.
- Use of commercial off-the-shelf (COTS) technology reduces the capital equipment cost by approximately one-third. The tradeoff of using COTS technology versus custom-built equipment occurs with operator training, start-up assistance and documentation. The custom-built equipment provides these services as part of the contract cost.
- The Met-Pro Corporation Duall Division equipment includes a chemical feed pumping system, instrumentation to operate and monitor the process, and a control panel that contains a supply power, parameter indication, alarms, and process interlocks. Installation of this equipment requires additional site preparation, electrical, piping, mechanical, instrumentation and operating and maintenance requirements. Factoring in these additional requirements increases base equipment cost from \$34,800 to \$79,350 for installation and \$57,300 for yearly operation.

Appendix A: Extracts of Reports and Regulations Relating to Air Emissions

**MALCOLM
PIRNIE**

IWTP Extract 6/6/2001 *JPB*

**AIR EMISSIONS INVENTORY
WATERVLIET ARSENAL,
Watervliet, New York**

ATTACHMENT 1

**Baltimore Corps of Engineers
Baltimore, Maryland**

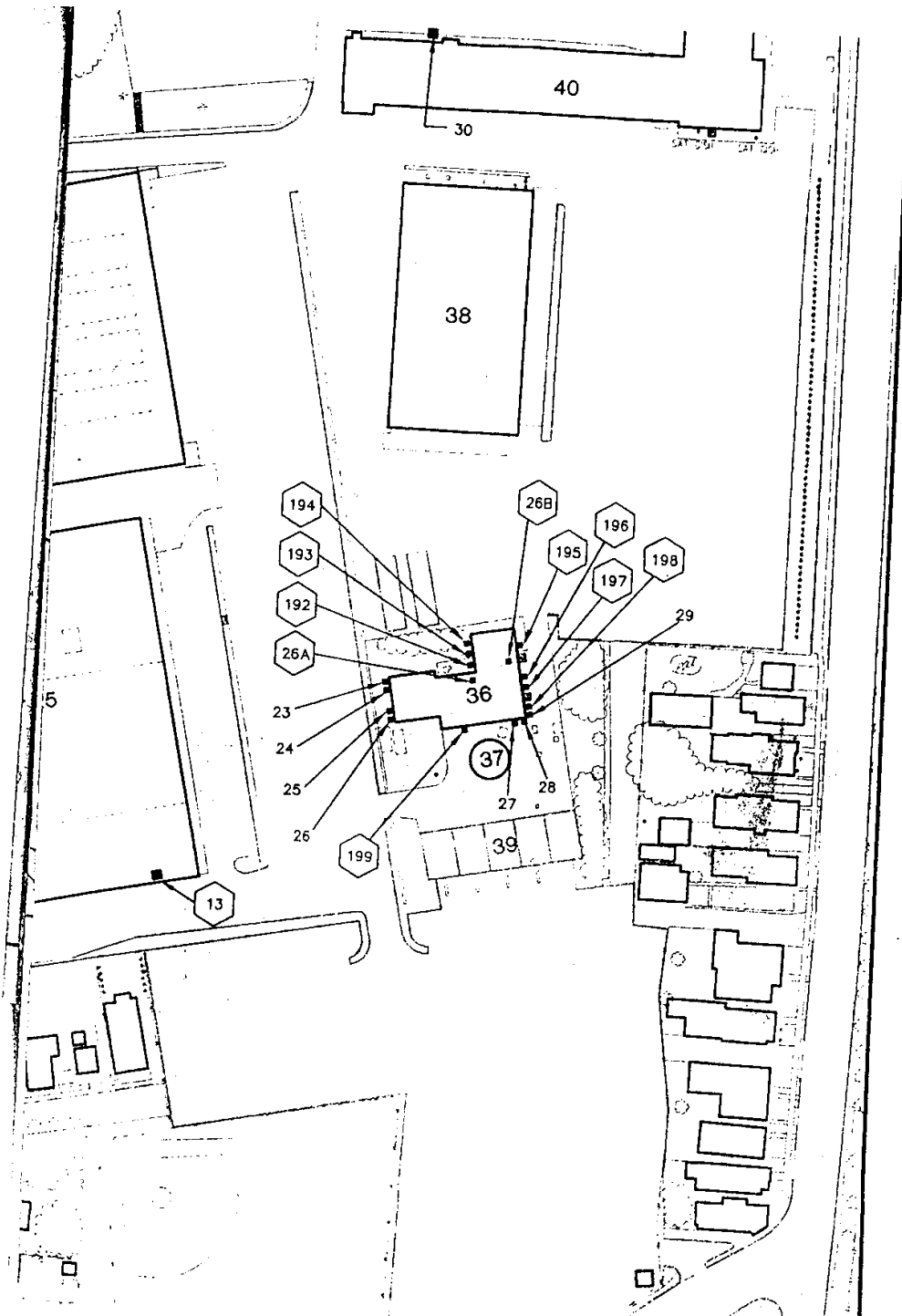


**US Army Corps
of Engineers**
Baltimore District
DRIVEN BY A VISION...to be the BEST

Prepared by:

Malcolm Pirnie, Inc.
15 Cornell Road
Latham, New York 12110

September 1997
0285-610



Source Emissions Calculation

EMISSION POINT: 26A

Assumed existing permit calculations valid based on stack testing.

NEW YORK STATE
DEPARTMENT OF ENVIRONMENTAL CONSERVATION

PROCESS, EXHAUST OR VENTILATION SYSTEM
APPLICATION FOR PERMIT TO CONSTRUCT OR CERTIFICATE TO OPERATE

1. NAME OF PROJECT: Department of the Army, Waterfront Arsenal
2. NAME OF AUTHORIZED AGENT: John J. Karkis
3. TELEPHONE: 0652-4176-5716
4. FACILITY NAME (IF DIFFERENT FROM OWNER / FROM):
5. FACILITY LOCATION NUMBER AND STREET ADDRESS:
6. CITY - TOWN - VILLAGE: Waterfront, NY
7. BUILDING NAME OR NUMBER: 36
8. FLOOR NAME OR NUMBER: First
9. STATE: NY
10. ZIP: 12089-4350
11. NAME OF P.E. OR ARCHITECT: John J. Karkis
12. P.E. OR ARCHITECT LICENSE NO.: 0652-4176-5716
13. SIGNATURE OF OWNER REPRESENTATIVE: John J. Karkis
14. SIGNATURE OF ENGINEER REPRESENTATIVE: John J. Karkis
15. PERMIT TO CONSTRUCT: ☒ NEW SOURCE
16. CERTIFICATE TO OPERATE: ☒ EXISTING SOURCE
17. MODIFICATION: ☐ MODIFICATION
18. SOURCE CODE: 2801
19. HOURS / DAY: 24
20. DAYS / WEEK: 365
21. WINTER: 2.5
22. SPRING: 2.5
23. SUMMER: 2.5
24. FALL: 2.5

25. CHRONIC ACID RAINFALL: 1

26. CALCULATIONS: Hourly Emissions: Hourly emission rate was developed from stack test data on a similar source (EP0026B). Annual Emissions: 99,000 lbs/year SO₂ x 1.12% emission factor = 1,092 lbs SO₂ emitted. The emission factor was developed from stack test data on a similar source (EP0026B).
NOTE: EP0026A and EP0026B are similar sources in the same building. The emission rates on this application may be obtained from either EP0026A or EP0026B, or from the combination of both emission points. The summation of hourly and annual emissions from EP0026A and EP0026B will not exceed 1.3 lb/hr and 1044 lbs/year, respectively.

27. CONTAMINANT: Sulfur dioxide
28. CAS NUMBER: 7784-85-9
29. EMISSIONS: 1.30
30. PERMISSIBLE: 1.30
31. ANNUAL EMISSIONS: 1044

32. TYPE: SOLID FUEL
33. THOUSANDS OF GALLONS/YR: 1.30
34. TYPE: LIQUID FUEL
35. THOUSANDS OF GALLONS/YR: 1.30
36. TYPE: GAS
37. THOUSANDS OF GALLONS/YR: 1.30
38. TYPE: OTHER
39. THOUSANDS OF GALLONS/YR: 1.30
40. APPLICABLE RULE: 213
41. APPLICABLE RULE: 154

42. PERMIT TO CONSTRUCT: ☒ PERMIT TO CONSTRUCT
43. CERTIFICATE TO OPERATE: ☒ CERTIFICATE TO OPERATE
44. SIGNATURE OF AUTHORIZED REPRESENTATIVE OR AGENT: John J. Karkis
45. DATE: 02/06/96

46. SPECIAL CONDITIONS: NONE

Source Emissions Calculation

EMISSION POINT: 26B

Assumed existing permit calculations valid based on stack testing.

LOCATION: NEW YORK STATE DEPARTMENT OF ENVIRONMENTAL CONSERVATION		COUNTY: GREENE OFFICE: GREENE WHITE: GREENE YELLOW: APPLICANT	
PROCESS, EXHAUST OR VENTILATION SYSTEM APPLICATION FOR PERMIT TO CONSTRUCT OR CERTIFICATE TO OPERATE			
1. NAME OF OWNER / TYPE Department of the Army Waterfront Arsenal		10. TELEPHONE 266-5726	
2. NUMBER AND STREET ADDRESS Brandywine ATTN: STATION 15H		11. NUMBER AND STREET ADDRESS Brandywine ATTN: STATION 15H	
3. CITY, TOWN, VILLAGE Waterfront		12. CITY, TOWN, VILLAGE Waterfront	
4. STATE NY		13. STATE NY	
5. ZIP 12183		14. ZIP 12183	
6. OTHER IDENTIFICATION Waterfront Arsenal		15. BUILDING NAME OR NUMBER 36	
7. FLOOR NAME OR NUMBER First		16. FLOOR NAME OR NUMBER First	
8. NAME OF P.E. OR ARCHITECT James J. Kardis		17. NAME OF P.E. OR ARCHITECT James J. Kardis	
9. SIGNATURE OF OWNER REPRESENTATIVE OR AGENT WHEN APPLICING FOR A PERMIT TO CONSTRUCT Director of Installation Services		18. SIGNATURE OF OWNER REPRESENTATIVE OR AGENT WHEN APPLICING FOR A PERMIT TO CONSTRUCT Director of Installation Services	
19. PERMIT TO CONSTRUCT <input type="checkbox"/> NEW SOURCE <input type="checkbox"/> MODIFICATION		20. CERTIFICATE TO OPERATE <input type="checkbox"/> NEW SOURCE <input checked="" type="checkbox"/> MODIFICATION	
21. START UP DATE 12/1/83		22. DRAINAGE NUMBERS OF PLANS SUBMITTED 10	
23. DATE OF PERMIT TO CONSTRUCT 12/1/83		24. DATE OF CERTIFICATE TO OPERATE 12/1/83	
25. PERMIT TO CONSTRUCT 30		26. CERTIFICATE TO OPERATE 30	
27. PERMIT TO CONSTRUCT 30		28. CERTIFICATE TO OPERATE 30	
29. PERMIT TO CONSTRUCT 30		30. CERTIFICATE TO OPERATE 30	
31. PERMIT TO CONSTRUCT 30		32. CERTIFICATE TO OPERATE 30	
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39. PERMIT TO CONSTRUCT 30		40. CERTIFICATE TO OPERATE 30	
41. PERMIT TO CONSTRUCT 30		42. CERTIFICATE TO OPERATE 30	
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45. PERMIT TO CONSTRUCT 30		46. CERTIFICATE TO OPERATE 30	
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51. PERMIT TO CONSTRUCT 30		52. CERTIFICATE TO OPERATE 30	
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67. PERMIT TO CONSTRUCT 30		68. CERTIFICATE TO OPERATE 30	
69. PERMIT TO CONSTRUCT 30		70. CERTIFICATE TO OPERATE 30	
71. PERMIT TO CONSTRUCT 30		72. CERTIFICATE TO OPERATE 30	
73. PERMIT TO CONSTRUCT 30		74. CERTIFICATE TO OPERATE 30	
75. PERMIT TO CONSTRUCT 30		76. CERTIFICATE TO OPERATE 30	
77. PERMIT TO CONSTRUCT 30		78. CERTIFICATE TO OPERATE 30	
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81. PERMIT TO CONSTRUCT 30		82. CERTIFICATE TO OPERATE 30	
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89. PERMIT TO CONSTRUCT 30		90. CERTIFICATE TO OPERATE 30	
91. PERMIT TO CONSTRUCT 30		92. CERTIFICATE TO OPERATE 30	
93. PERMIT TO CONSTRUCT 30		94. CERTIFICATE TO OPERATE 30	
95. PERMIT TO CONSTRUCT 30		96. CERTIFICATE TO OPERATE 30	
97. PERMIT TO CONSTRUCT 30		98. CERTIFICATE TO OPERATE 30	
99. PERMIT TO CONSTRUCT 30		100. CERTIFICATE TO OPERATE 30	
101. PERMIT TO CONSTRUCT 30		102. CERTIFICATE TO OPERATE 30	
103. PERMIT TO CONSTRUCT 30		104. CERTIFICATE TO OPERATE 30	
105. PERMIT TO CONSTRUCT 30		106. CERTIFICATE TO OPERATE 30	
107. PERMIT TO CONSTRUCT 30		108. CERTIFICATE TO OPERATE 30	

Source Emissions Calculation

EMISSION POINT:		192		UNIT: IWTP - Lime mixing tank	
SOURCE DATA					
Operating Schedule		1 hr/day 1 day/wk 50 days/yr 50 hr/yr			
MATERIAL DATA					
Hydrated Lime		7500 lb/yr			
POLLUTION CONTROL EQUIPMENT					
None		Efficiency:		0 %	
Pollutant	EMISSIONS				
	ERP	ACTUAL			
	lb/hr	lb/hr	lb/day	lb/yr	ton/yr
Particulate	0.150	0.150	0.150	7.500	0.004
EMISSIONS CALCULATIONS					
$ERP \text{ (lb/hr)} = PLF/100 \times \text{MATERIAL USE (lbs/hr)} / \text{HOURS OF OPERATION PER YEAR}$ $ACTUAL \text{ (lb/hr)} = ERP \text{ (lb/hr)} \times (1 - \text{CONTROL EFF}/100)$ $(\text{lb/day}) = \text{lb/hr} \times \text{hr/day}$ $(\text{lb/yr}) = \text{lb/day} \times \text{day/yr}$ $(\text{ton/yr}) = \text{lb/yr} / 2000 \text{ lb/ton}$					
COMMENTS					
Assumed PLF from existing permit					
PLF =		0.1 %			
Quantity of materials emitted to the air is based on inventory data sheet, interview data, and MSDS information.					

Source Emissions Calculation

EMISSION POINT: 193		UNIT: IWTP - #2 Blend Tank			
SOURCE DATA					
Operating Schedule		12 hr/day 6 day/wk 300 days/yr 3600 hr/yr			
Gas Flow Rate	300 cfm =	301.7 scfm			
MATERIAL DATA					
Microbial action creates hydrogen sulfide a concentration of		2 ppm			
POLLUTION CONTROL EQUIPMENT					
None		Efficiency: 0 %			
Pollutant	EMISSIONS				
	ERP lb/hr	lb/hr	lb/day	lb/yr	ton/yr
Hydrogen Sulfide	0.0027	0.0027	0.0326	9.7751	0.0049
EMISSIONS CALCULATIONS					
GAS FLOW RATE (scfm) = CFM x (Standard Temp. + 460) / (Operating Temp + 460) ERP (lb/hr) = PLF/100 x CONC. (ppm) x GAS FLOW RATE (scfh) x DENSITY OF AIR ACTUAL (lb/hr) = ERP (lb/hr) x (1 - CONTROL EFF/100) (lb/day) = lb/hr x hr/day (lb/yr) = lb/day x day/yr (ton/yr) = lb/yr / 2000lb/ton					
COMMENTS					
Assumed Hydrogen sulfide is generated by microbial action at a conc of 2 ppm.					
Assumed Standard Temp. =		68 degrees F			
Operating Temp. =		65 degrees F			
Density of Air =		0.0749 lbs/cf			
POLLUTION LOADING FACTOR		100 %			
Quantity of materials emitted to the air is based on inventory data sheet, interview data, and MSDS information.					

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Source Emissions Calculation

EMISSION POINT:		194		UNIT: IWTP - Clarifier Tanks	
SOURCE DATA					
Operating Schedule		24 hr/day 7 day/wk 350 days/yr 8400 hr/yr			
Gas Flow Rate		1750 cfm	=	1760 scfm	
MATERIAL DATA					
Microbial action creates hydrogen sulfide a concentration of		2 ppm			
POLLUTION CONTROL EQUIPMENT					
None		Efficiency:		0 %	
Pollutant	EMISSIONS				
	ERP	ACTUAL			
	lb/hr	lb/hr	lb/day	lb/yr	ton/yr
Hydrogen Sulfide	0.0158	0.0158	0.3802	133.0560	0.0665
EMISSIONS CALCULATIONS					
GAS FLOW RATE (scfm) = CFM x (Standard Temp. + 460) / (Operating Temp +460) ERP (lb/hr) = PLF/100 x CONC. (ppm) x GAS FLOW RATE (scfh) x DENSITY OF AIR ACTUAL (lb/hr) = ERP (lb/hr) x (1 - CONTROL EFF/100) (lb/day) = lb/hr x hr/day (lb/yr) = lb/day x day/yr (ton/yr) = lb/yr /2000lb/ton					
COMMENTS					
Assumed Hydrogen sulfide is generated by microbial action at a conc of 2 ppm.					
Assumed Standard Temp. =		68 degrees F			
Operating Temp. =		65 degrees F			
Density of Air =		0.0749 lbs/cf			
POLLUTION LOADING FACTOR		100 %			
Quantity of materials emitted to the air is based on inventory data sheet, Interview data, and MSDS information.					

Source Emissions Calculation

EMISSION POINT:		195		UNIT: IWTP - Soluble Oil Batch Tank	
SOURCE DATA					
Operating Schedule		24 hr/day 6 day/wk 300 days/yr 7200 hr/yr			
Gas Flow Rate		1750 cfm	=	1760 scfm	
MATERIAL DATA					
Microbial action creates hydrogen sulfide a concentration of		2 ppm			
POLLUTION CONTROL EQUIPMENT					
None		Efficiency:		0 %	
Pollutant	EMISSIONS				
	ERP	ACTUAL			
	lb/hr	lb/hr	lb/day	lb/yr	ton/yr
Hydrogen Sulfide	0.0158	0.0158	0.3802	114.0480	0.0570
EMISSIONS CALCULATIONS					
GAS FLOW RATE (scfm) = CFM x (Standard Temp. + 460) / (Operating Temp +460) ERP (lb/hr) = PLF/100 x CONC. (ppm) x GAS FLOW RATE (scfh) x DENSITY OF AIR ACTUAL (lb/hr) = ERP (lb/hr) x (1 - CONTROL EFF/100) (lb/day) = lb/hr x hr/day (lb/yr) = lb/day x day/yr (ton/yr) = lb/yr /2000lb/ton					
COMMENTS					
Assumed Hydrogen sulfide is generated by microbial action at a conc of 2 ppm.					
Assumed Standard Temp. =		68 degrees F			
Operating Temp. =		65 degrees F			
Density of Air =		0.0749 lbs/cf			
POLLUTION LOADING FACTOR		100 %			
Quantity of materials emitted to the air is based on inventory data sheet, interview data, and MSDS information.					

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Source Emissions Calculation

EMISSION POINT:		196		UNIT: IWTP - Sludge Tank	
SOURCE DATA					
Operating Schedule		2 hr/day 6 day/wk 300 days/yr 600 hr/yr			
Gas Flow Rate		300 cfm =		301.7 scfm	
MATERIAL DATA					
Microbial action creates hydrogen sulfide a concentration of		5 ppm			
POLLUTION CONTROL EQUIPMENT					
None		Efficiency:		0 %	
Pollutant	EMISSIONS				
	ERP lb/hr	lb/hr	lb/day	lb/yr	ton/yr
Hydrogen Sulfide	0.0068	0.0068	0.0136	4.0730	0.0020
EMISSIONS CALCULATIONS					
GAS FLOW RATE (scfm) = CFM x (Standard Temp. + 460) / (Operating Temp +460) ERP (lb/hr) = PLF/100 x CONC. (ppm) x GAS FLOW RATE (scfm) x DENSITY OF AIR ACTUAL (lb/hr) = ERP (lb/hr) x (1 - CONTROL EFF/100) (lb/day) = lb/hr x hr/day (lb/yr) = lb/day x day/yr (ton/yr) = lb/yr /2000lb/ton					
COMMENTS					
Assumed Hydrogen sulfide is generated by microbial action at a conc of 5 ppm.					
Assumed Standard Temp. =		68 degrees F			
Operating Temp. =		65 degrees F			
Density of Air =		0.0749 lbs/cf			
POLLUTION LOADING FACTOR		100 %			
Quantity of materials emitted to the air is based on inventory data sheet, interview data, and MSDS information.					

Source Emissions Calculation

EMISSION POINT: 197		UNIT: IWTP - Aluminum Sulfate mixing tank			
SOURCE DATA					
Operating Schedule		3 hr/day 6 day/wk 300 days/yr 900 hr/yr			
MATERIAL DATA					
Aluminum Sulfate (Alum)		64400 lb/yr			
POLLUTION CONTROL EQUIPMENT					
None		Efficiency: 95 %			
Pollutant	EMISSIONS				
	ERP lb/hr	lb/hr	lb/day	lb/yr	ton/yr
Particulate	0.072	0.004	0.011	3.220	0.002
EMISSIONS CALCULATIONS					
ERP (lb/hr) = PLF/100 x MATERIAL USE (lbs/hr) / HOURS OF OPERATION PER YEAR					
ACTUAL (lb/hr) = ERP (lb/hr) x (1 - CONTROL EFF/100)					
(lb/day) = lb/hr x hr/day					
(lb/yr) = lb/day x day/yr					
(ton/yr) = lb/yr / 2000lb/ton					
COMMENTS					
Assumed PLF from existing permit					
PLF = 0.1 %					
Quantity of materials emitted to the air is based on inventory data sheet, interview data, and MSDS information.					

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Source Emissions Calculation

EMISSION POINT:		198		UNIT: IWTP - Polyelectrolytic mixing tank	
SOURCE DATA					
Operating Schedule		1 hr/day 6 day/wk 300 days/yr 300 hr/yr			
MATERIAL DATA					
Polyelectrolyte		1500 lb/yr			
POLLUTION CONTROL EQUIPMENT					
None		Efficiency:		0 %	
Pollutant	EMISSIONS				
	ERP	ACTUAL			
	lb/hr	lb/hr	lb/day	lb/yr	ton/yr
Particulate	0.00500	0.00500	0.00500	1.50000	0.00075
VOCs	0.50000	0.50000	0.50000	150.00000	0.07500
EMISSIONS CALCULATIONS					
ERP (lb/hr) = PLF/100 x MATERIAL USE / HOURS OF OPERATION PER YEAR					
ACTUAL (lb/hr) = ERP (lb/hr) x (1 - CONTROL EFF/100)					
(lb/day) = lb/hr x hr/day					
(lb/yr) = lb/day x day/yr					
(ton/yr) = lb/yr / 2000lb/ton					
COMMENTS					
Assumed PLF from existing permit					
PLF for Particulates = 0.1 % (based on existing permit)					
PLF for VOCs = 10 % (based on MSDS)					
Quantity of materials emitted to the air is based on inventory data sheet, interview data, and MSDS information.					

Source Emissions Calculation

EMISSION POINT:		199		UNIT: IWTP - #1 Blend Tank	
SOURCE DATA					
Operating Schedule		12 hr/day 6 day/wk 300 days/yr 3600 hr/yr			
Gas Flow Rate		300 cfm	=	301.7 scfm	
MATERIAL DATA					
Microbial action creates hydrogen sulfide a concentration of		2 ppm			
POLLUTION CONTROL EQUIPMENT					
None		Efficiency:		0 %	
Pollutant	EMISSIONS				
	ERP	ACTUAL			
	lb/hr	lb/hr	lb/day	lb/yr	ton/yr
Hydrogen Sulfide	0.0027	0.0027	0.0326	9.7751	0.0049
EMISSIONS CALCULATIONS					
GAS FLOW RATE (scfm) = CFM x (Standard Temp. + 460) / (Operating Temp + 460) ERP (lb/hr) = PLF/100 x CONC. (ppm) x GAS FLOW RATE (scfh) x DENSITY OF AIR ACTUAL (lb/hr) = ERP (lb/hr) x (1 - CONTROL EFF/100) (lb/day) = lb/hr x hr/day (lb/yr) = lb/day x day/yr (ton/yr) = lb/yr / 2000 lb/ton					
COMMENTS					
Assumed Hydrogen sulfide is generated by microbial action at a conc of 2 ppm.					
Assumed Standard Temp. =		68 degrees F			
Operating Temp. =		65 degrees F			
Density of Air =		0.0749 lbs/cf			
POLLUTION LOADING FACTOR		100 %			
Quantity of materials emitted to the air is based on inventory data sheet, Interview data, and MSDS information.					

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REPLY TO
ATTENTION OF

CECER-ULI (70-1y)

DEPARTMENT OF THE ARMY
CONSTRUCTION ENGINEERING RESEARCH LABORATORIES, CORPS OF ENGINEERS
P.O. BOX 9005
CHAMPAIGN, ILLINOIS 61826-9005



DANA LEVY
SIOWV-ISH
13 MAY 1996

3 May 96

MEMORANDUM FOR Commander, Watervliet Arsenal, ATTN: SIOWV-AT
(P. Darcy), Building 10, Watervliet, New York 12189-4050

SUBJECT: Submission of Report #1

1. Reference accepted project order proposal "IWTP Sulfur Emissions Control", 29 Aug 95.
2. Enclosed are two copies of Report #1 titled, "Sulfur Emission at the Watervliet Arsenal Industrial Wastewater Treatment Plant, Report #1: Identification and Potential Solutions, 30 Apr 96."
3. This report completes the first of three stages as outlined in the referenced project order.
4. Please review the enclosed report. After your review please contact me to discuss direction of the second stage regarding method choice and development. I can be reached at (217)373-3485 or (800)USA-CERL, x3485.

Encl

K. JAMES HAY, Ph.D.
Chemical Engineer
Industrial Operations Division

CF (w/encl.):
CDR, Watervliet Arsenal SIOWV-ISH (J. Kardas)
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SULFUR EMISSIONS AT THE WATERVLIET ARSENAL INDUSTRIAL WASTEWATER TREATMENT PLANT

**Report #1: Identification and Potential Solutions
30 April 1996**

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1. Introduction

Watervliet Arsenal possesses a large hexavalent chromium electroplating facility that generates chromic acid wastewater. This waste stream is treated by an industrial wastewater treatment plant (IWTP) and discharged into the Hudson River. The current acid waste treatment process utilizes a large sulfur intake. Sulfuric acid is added to the waste stream to lower the pH, sulfur dioxide is added to reduce the hexavalent chromium to trivalent chromium, and aluminum sulfate (alum) is used to assist in the precipitation of the trivalent chromium. Although the IWTP possesses a New York State air permit, there has been concern for the odor generated by the plant. The odor may be attributed to the generation of hydrogen sulfide (H_2S) or the addition of excess sulfur dioxide (SO_2) to the acid waste treatment process. Watervliet Arsenal has asked the U.S. Army Construction Engineering Laboratories (USACERL) to identify and develop a method that will solve this problem.

This project has three phases: (1) the investigation to determine the nature and cause of any sulfur emissions as well as determining potential solutions, (2) the development of the chosen solution methods, and (3) method implementation. This report signifies the end of the first phase. It is intended to present the findings of experiments performed at the IWTP, characterize the emissions and probable causes, list the available options for correcting any problems found, and to give a recommendation on which options should be developed.

2. Background

The IWTP has three waste treatment processes: the acid waste treatment line, the soluble oil waste treatment line, and the cyanide waste treatment line. The respective yearly treatment rates are 25,000,000 gallons per year, 5,000,000 gallons per year, and 17,000 gallons per year. The effluent from both the cyanide and soluble oil treatment processes return to the acid receiving well for a second treatment in the acid waste process.

The soluble oil treatment process is a batch process with two 6,700 gallon batch tanks with a treatment rate anywhere from one to six batches per day. Apparently, more treatments occur during the fall and spring due to more rainfall. The batch tanks slowly fill with influent, once full they are treated immediately. Treatment consists of adding sulfuric acid and alum to lower the pH to four or five and disperse the oil emulsion; the addition of sodium hydroxide to raise the pH to eight; the addition of polyelectrolyte to generate precipitate; the settling of the sludge (30 to 60 minutes); and the removal of the batch contents. This later step includes removing the combustible skim oil off the top to a holding tank, conveying the sludge to the drying beds, and directing the noncombustible soluble oil waste effluent to the acid waste receiving well. The batch process from the addition of sulfuric acid usually takes no more than two hours.

The acid waste process is intended to treat the hexavalent chromium waste generated by the large chromium electroplating operations at the Arsenal. The idea is to precipitate out the chromium in the less toxic trivalent state to be disposed. Waste from the electroplating operations are usually directed towards the acid receiving well or to either one of two storage tanks (75,000 and 39,000 gallon capacities) to be processed. The process influent is treated with sulfuric acid to reduce the pH to about 2.5. There are two treatment lines with flow capacities of 120 gallons per minute. For each process line, pressurized sulfur dioxide is injected into the process stream to reduce the hexavalent chromium to trivalent chromium. Currently, the addition of sulfur dioxide is performed manually and adjusted based on the color of the sulfonated influent. The operators can also use the pH and oxidation reduction potential meters for process feedback. New automated process controls are currently being installed. The sulfonated influent flows into a reaction tank where the reduction is completed and then treated with sodium hydroxide is added to raise the pH to about eight. The addition of sodium hydroxide initiates the production of the trivalent chromium precipitate. The stream is then directed towards a blending tank where alum is added. The flow is then pumped to one of two clarifiers where polyelectrolyte is added to enhance settling of the precipitate. Sludge forms on the bottom of the clarifiers where it is periodically transferred to the drying beds. The "clean water" effluent from the clarifiers is discharged to the river.

More detailed process information and schematics can be found in the IWTP concept report (Robson and Woese, Inc. and Stearns & Wheler, January 1988). Currently there are no air emission control devices installed at the plant. However, all tanks are ventilating by blowers operating continuously.

3. Experimental Investigation

Experiment #1

1995

On 11 December 1996 experiments were performed at the IWTP to identify and characterize any sulfur emissions from the major emission points, in particular the emissions from reaction tank #1 (tank #2 was not operating at the time) and the clarifiers. The test was performed on a Monday (after the weekend shutdown) because worker testimony indicated that odors were more prevalent at times of plant startup. During the test an influent containing near 250 ppm of hexavalent chromium was being treated, and between 600 and 700 lbs/day of sulfur dioxide was injected into the process line. Results indicated no hydrogen sulfide emitted from any of the emission points. Low concentrations of sulfur dioxide were measured emitting from the reaction tank at an average concentration of 2.9 ppm or a mass rate of 0.012 lbs/hour. The measured volumetric flow rate exiting this six inch diameter stack was 415 dscf/min. With a total sulfur dioxide input of 650 lbs/day, the emissions represent a 0.044% escape rate (USACHPPM, 1995).

Experiment #2

The results from the first experiment are somewhat puzzling. Testimony of the operators of the plant suggested that hydrogen sulfide odors should be present at startup of the plant after a weekend and higher sulfur dioxide concentrations were expected. Further worker testimony indicated that the odor problem was only present during warmer times of the year (summer). This information pointed towards a microorganism problem as possible answer for any hydrogen sulfide produced. Further worker testimony also indicated that a portable sulfur dioxide monitor held near the reaction tank stack indicated concentrations greater than twenty parts per million during the treatment of high chromium concentration influent. To test these suspicions, this second experiment was arranged.

The second test took place on 28 February 1996. There were two parts to the experiment: testing for sulfur dioxide emissions from reaction tank #2 (reaction tank #1 was not operating at the time of the experiment) and biological samples from several points in the process.

Biological Sampling

It is suspected that sulfate reducing bacteria (SRB) are the source of the claimed hydrogen sulfide odor. To check this suspicion, biological samples were taken from the top of the clarifier, the sludge effluent, and the oil waste treatment effluent (after entering the acid waste treatment receiving well). The clarifier and sludge samples were taken from clarifier #1 which had just been cleaned, painted, and started up one week prior to the testing (clarifier #2 was empty at the time of sampling). This coupled with the low winter outside temperatures suggests that this was a time of expected lowest bioactivity.

Three of the four samples were inoculated in a series of three steps of ten to one dilution at room temperature for two weeks. The inoculation sample bottles contained acetate/lactate

SRB medium with a nail inside as a source of iron. A positive sample is scored if a generous amount of very black precipitate, lead sulfide, is formed. Each consecutive positive sample indicates an order of magnitude greater number of SRB present in the sample. In addition, sulfate concentrations, total organic carbon (TOC), and the pH were measured for each sample. The following table summarizes the results of these tests:

Table 1. Results of biological sampling.

Sample	SRB conc. (number/ml)	Sulfate conc. (mM)	TOC (ppm)	pH
1-top of clarifier	test not done	4.2	12	7.2
2-clarifier sludge	>1000	6.4	17	8.0
3-side/top clarifier	100	4.5	10	7.5
4-Soluble oil effluent	>>1000	4.3	26	7.6

Sulfate concentration, TOC, and pH are within physiological limits capable of supporting SRB growth in all samples.

Sulfur Dioxide Sampling

A high hexavalent chromium concentration influent was created to simulate real conditions experienced at the IWTP periodically due to acid dumping or scrubber backwash at the plating operations. Sulfur dioxide stack sampling was performed on the stack of reaction tank #2 during the episode. The sampling began when the acid was sent down from the production area of the Arsenal down to the IWTP. The sulfur dioxide input was adjusted manually during the test (standard operational practice) to account for the increasing chromium concentration entering the process. The first part of the test spanned approximately two hours ending when the sulfur dioxide input was decreased due to the decreasing influent chromium concentration. During the test the peak concentration was 750 ppm chromium, with a maximum sulfur dioxide input of 2800 lbs/day. The maximum sulfur dioxide reading was 205 ppm. This corresponds to a mass flow rate of 1.2 lbs/hour. At these peak conditions, 1.0% of injected sulfur dioxide was emitted. Over the two hour period, the average sulfur dioxide emissions were 83 ppm, or 0.50 lbs/hour. Other measurements showed about 20 ppm of sulfur dioxide emitted from the blending tank (EF-6) shortly after the peak sulfur dioxide concentration from the reaction tank was reached (USACHPPM, 1996). This indicates that some desorption was occurring at this point in the process. Figure 1 shows the sulfur dioxide concentration measured every ten minutes during the testing period.

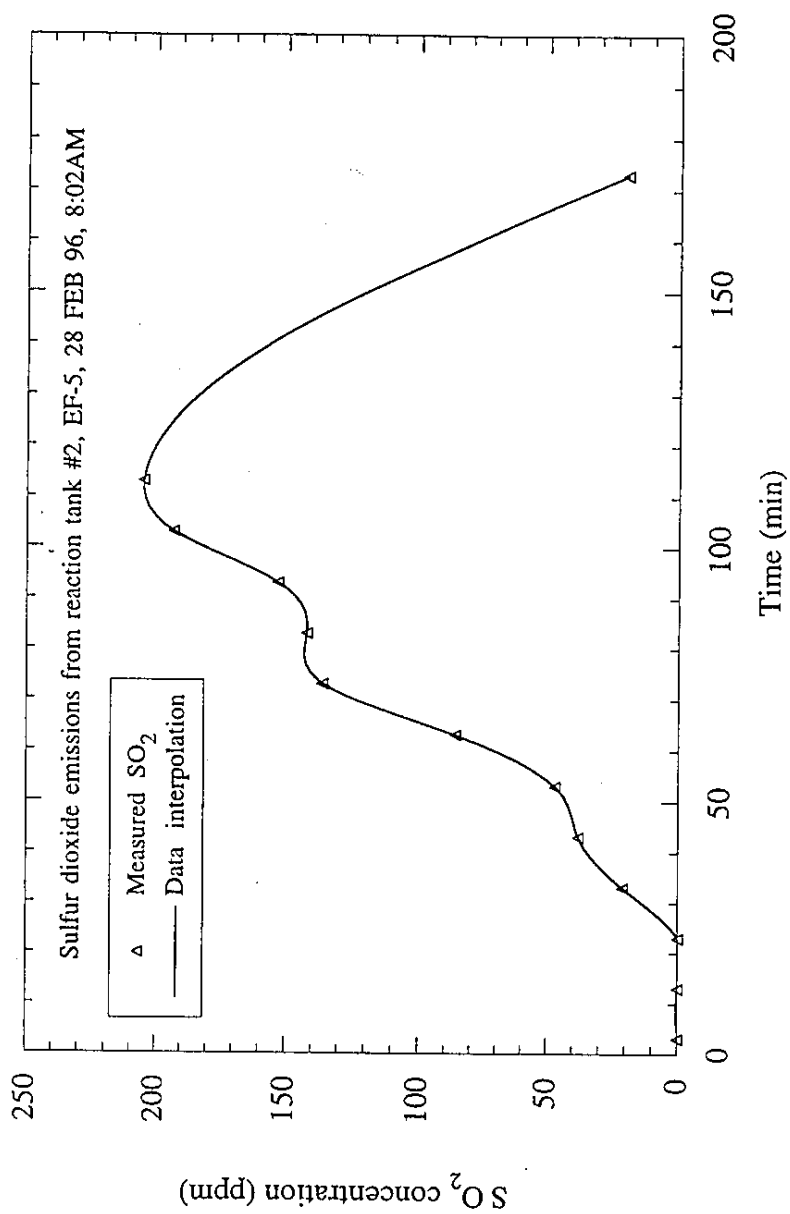


Figure 1. Measured sulfur dioxide emissions from reaction tank #2 during experiment #2.

4. Problem Definition

Hydrogen Sulfide Odors

The results of the biological samples show that sulfate-reducing microorganisms are present in all locations that samples were taken and that the conditions are conducive for SRB growth. It is interesting that the highest population observed was in the soluble oil waste effluent (or acid receiving well) sample. It is difficult to say whether this is normally the case or whether the recent clean and paint job significantly reduced the biomass in the clarifiers and consequently reduced the bacteria concentration in the liquid and sludge. Since the contents of the acid receiving well are eventually fed into the acid waste process, a positive sample here indicates that this well or the oil waste treatment process effluent is the source of the bacteria. This effluent is also a source of oil which consists of hydrocarbons for the bacteria to consume.

Although no hydrogen sulfide emissions were detected during the experiments, the gas is greatly suspected of being present during warmer times of the year based on worker testimony and the confirmed presence of SRB. Since temperature is one of the most important environmental variables effecting the growth of SRB, it is plausible that the increase in the growth rate of the SRB during the warmer summer months requires enough sulfate for growth that sufficient hydrogen sulfide is generated to cause odor problems. In addition there is noticeable black corrosion of metal parts within the treatment plant due to a reaction with hydrogen sulfide.

Based on the above discussion it is likely that SRB is the source of hydrogen sulfide, the effluent from the soluble oil waste process is the ultimate source of the bacteria into the acid waste process, and the oil remaining in this stream is the bacteria's food. The bacteria begins to flourish after the pH is brought up to near neutral conditions by the addition of sodium hydroxide (in the last section of the reaction tank). This is apparent by the buildup of biomass on the walls at this point, in the blend tanks, and in the clarifiers. The clarifiers are most suspect as the origin of the odors. With the process running, the fluid in the clarifier will replace itself approximately every 112 minutes removing dissolved hydrogen sulfide and bacteria suspended in the fluid. Bacteria multiplication and the increase in hydrogen sulfide concentration will occur most readily when the process flow has ceased and fluids/sludge remain.

It is a possibility that the odors come from the batch reaction tanks instead of or in addition to the clarifiers considering the high sulfate concentration in the effluent and concentrated food source for the SRB. Operational practices currently minimize the possibility of this being a significant problem. The batch process itself takes very little time from the time that conditions are favorable for SRB growth to begin (once sulfates are added and pH is brought to a neutral range) until the tank is drained, limiting potential SRB multiplication. This suggests that a significant problem will not exist in these batch tanks but if significant sulfate concentrations buildup in the tank before the process begins, a problem could be created.

Sulfur Dioxide Emissions

The operating condition of experiment #1 represent an above average sulfur dioxide mass input to the acid waste treatment process based on the annual amount of sulfur dioxide used. The estimated daily amount of sulfur dioxide used in 1995 was 300 lbs/day. During the test the average was 650 lbs/day. If the plant emitted 0.012 lbs/hour sulfur dioxide all year from both of the reaction tanks the total mass emissions would be approximately 173 lbs/year (assuming 300 days). These emissions easily fall within the permit guidelines of 1044 lbs/year. At the time of this experiment the permitted hourly rate from reaction tank #1 was 0.08 lbs/hr, the experiment showed 0.012 lbs/hour, so again the emissions were within this permit guideline. Assuming the permit levels represent emissions below hazardous levels, no hazard exists under these conditions.

The second experiment showed that under certain conditions of high chromium concentration influent to the acid waste treatment process, a relatively strong concentration of sulfur dioxide emissions can be vented to the atmosphere. On figure 1, between approximately 80 and 140 minutes the highest hourly concentration during the test of 173 ppm was achieved. This represents an emission rate of 1.0 lbs/hour. Making the crude assumption that this concentration is emitted no more than 10% of the time and 0.012 lbs/hour is emitted the other 90%, the emission rate would be 0.11 lbs/hour or 792 lbs/year. It should be recognized that both of these emission rates are for conditions of greater than average sulfur dioxide injection. This is an indication that the permitted value at the time of testing was surpassed and the potential exists for this to occur on a regular basis. It appears that the annual emission rate would be difficult to surpass under actual operations. At this hourly emission rate, it is possible that the permissible short term ground concentration was violated and a hazard may have existed for workers on the roof. The height of the stack at the time of testing was only about three feet above the roof surface. Even though it may be against standards of worker practice, the possibility existed that a worker could have leaned over the stack and been exposed to hazardous concentrations.

To remain in compliance, three conditions must be met: yearly permitted rate may not be exceeded, for any given hour no more than ten pounds of sulfur dioxide per hour may be exceeded, and New York ambient air standards may not be exceeded at the property line. The current standards are $80 \mu\text{g}/\text{m}^3$ as the Annual Ground Concentration (AGC) and $1400 \mu\text{g}/\text{m}^3$ as the Short term Ground Concentration (SGC). Using an emission dispersion model used by New York State officials to estimate ground concentrations (Air Guide 1), SGCs for a worst case concentration of 1.3 lbs/hour were calculated. Based on the model, the ground concentration standards are met if the stacks are at least 33 feet high. At the time of testing reaction tank #1 stack was at 31 feet and reaction tank #2 stack was at about 26 feet. Since these experiments, the Environmental Office of Watervliet Arsenal has applied for a permit modification to allow for an hourly emission rate of 1.3 lbs/hour total from both reaction tank stacks (it is a good assumption that this is the highest sulfur emission concentration to be emitted from the plant during any operational configuration, i.e. both sulfonators are injecting into the same process line at the full rate) and approval for raising both stacks to a height of 35 feet above ground. There was not a request for modifying the yearly rate. The modification has been approved. Currently, the stack heights are being raised. In light of this recent development, no regulatory problem exists.

5. Possible Solutions to Hydrogen Sulfide Problem

Although there is no emission evidence of hydrogen sulfide, its suspected presence is predictable. Hydrogen sulfide has a strong rotten egg like odor with a threshold as low as 0.0047 ppm. Concentrations higher than 20 ppm will cause physiological effects. Due to the difference in values, it is likely that the concentration surpasses the odor threshold but rarely reaches hazardous conditions. Testimony has indicated that the level has surpassed acceptable worker limits and there have been complaints originating from inside and outside of the plant. It is suggested that it is not good for worker morale nor good neighbor policy to ignore this problem further and applying a solution is recommended. Possible options for solving this problem are listed below. Testing could be performed during the summer to determine the extent and risk of the problem.

Option 1: Operational Modifications

An operational plan incorporating the following modifications will slow the buildup of bacteria and hydrogen sulfide by decreasing the actual residence time of the process stream in the process tanks and by periodically removing accumulated biomass. However, it will not cease bioactivity and a potential odor problem will remain.

Empty Clarifiers

Empty clarifiers fluids and sludge when not used for more than one week. This is particularly important during the warm summer months. The estimated cost impact would be roughly eight man hours (or \$600) every time a clarifier is emptied.

Minimize Residence Times

Avoid letting fluid remain in any tanks with process flow stopped by developing a process schedule that minimizes actual residence times in the process tanks, in particular the clarifiers. A possible schedule may be to switch process flow between the two clarifiers every eight hour shift. Ideally, running both clarifiers simultaneously would minimize residence time the most. The cost impact here would be negligible.

Desludge Often

Removing the sludge from the clarifiers on a frequent basis will minimize the biomass accumulation and hydrogen sulfide production at the bottom of the clarifiers. This would have a negligible cost impact.

Clean Process Tanks

Schedule routine tank cleanings. Even with the applying the above suggestions, a biofilm will develop over time. As the size of the biomass increases, the hydrogen sulfide production increases. A periodic cleaning will eliminate the biomass temporarily. Applying a biocide during cleaning may be helpful as well. The cost estimate to clean both clarifiers is about \$15,000.

Option 2: Treatment of Sulfate Reducing Bacteria

Exterminating the bacteria is a difficult proposition. The bacteria is throughout the process and eliminating it at one point will not stop the accumulation at others. In addition, a nonoxidizing bactericide would need to be used to avoid oxidizing the trivalent chromium back to hexavalent chromium after the reaction tank. This leaves two options for treating the SRB, a quaternary ammonium bactericide and the addition of calcium nitrate. Both are not recommended since the clarifier water containing these chemicals is discharged to the river.

Nonoxidizing Biocides

Biocides inhibit and often kill bacteria upon contact. Nonoxidizing bacteria, such as quaternary ammonium compounds, would need to be used in this case to prevent reoxidizing of the chromium. Inhibiting the growth of the SRB in the oil soluble effluent may be sufficient to prevent accumulation in the acid process. For one quaternary ammonium compound on the market, the cost would be about \$37.60 per 1000 gallons treated. This translates to an annual cost of \$188,000 (capital costs would be minimal). In addition to the very large costs, the biocide entering the river at usage strength will probably not be acceptable from a regulatory perspective.

Calcium Nitrate Addition

Adding calcium nitrate to the acid receiving well would inhibit the growth of SRB. The nitrate ion is preferred as an electron acceptor over sulfate by bacteria and will be utilized first. The increase in redox potential from the production of nitric oxide and nitrous oxide inhibits the growth of the SRB. The annual cost would be about \$15,000. It is doubtful that a 1-2 mM concentration of nitrates will be allowed to be discharged to the river.

Option 3: Removal of Food Source

Ultimately removing the food source, the oil in the soluble oil effluent, from the bacteria would provide the best chance for eliminating the problem. There are several ways of doing this: adsorb the hydrocarbons from this stream using granular activated carbon (GAC), destroy the hydrocarbons in this stream through nonsulfate reducing bioactivity, destroy the hydrocarbons through UV irradiation, or divert the soluble oil effluent away from the acid treatment process.

Granular Activated Carbon Adsorption

GAC is effective in removing hydrocarbons by adsorption from aqueous streams. An in-line reactor could be added between the batch reactor and the acid receiving well. The GAC would need to be replaced periodically. The used GAC would either be disposed of or regenerated to be used again in the reactor. It will require 8,300 pounds of GAC to treat five million gallons containing 20 ppm oil. An available commercial unit can handle 60

gallons per minute. Two units would need to be purchased for a total capital cost of \$30K. The units would be rotated back and forth and the carbon regenerated in the idle unit offsite. The annual cost greatly depends on the amount on the organic loading which determines the number of units. Estimating that four unit cycles would be used per year, the annual costs would be approximately \$800 plus shipping charges (expected to be significant - \$8K). It is expected that the effluent concentration would be reduced to less than 5 ppb, a concentration too low to sustain biological colonization. The unit has dimensions of six feet wide by six feet long by 8 feet tall; space allocation would be an issue for this device.

UV Irradiation

UV radiation will oxidize the hydrocarbons to carbon dioxide, destroying the carbon substrates preventing SRB growth. It also is effective in destroying the bacteria themselves. The annual cost for treating the oil soluble effluent before entering the acid receiving well would be roughly \$1000. The capital costs are unknown at this time.

Aerobic Biofilter

An aerobic biofilter will biologically oxidize the dissolved hydrocarbons to carbon dioxide and water. As with UV irradiation, destroying the substrates will prevent SRB from growing. However, this technology is not recommended due to the batch nature of the process effluent that it would be treating and the fragile nature of the biomass. It would be difficult to maintain a healthy colony without a continuous supply of food. The capital costs would be between \$30,000 and \$40,000 with annual costs of \$500.

Discharge Soluble Oil Effluent

Rerouting the soluble oil effluent away from the acid treatment process to be discharged to the river stands the highest chance of success because the food and major bacteria supply would be completely eliminated. However, there are two major issues involved. First, the effluent must meet all applicable standards for discharge. To ensure a compliant discharge, a series of chemical analysis would need to be performed and a means of periodic testing established. If standards are met, modifications would need to be made to the existing permit. There is no guarantee that a modification to treat this stream less would be approved nor that it will be evaluated on a timely basis. Second, a 20% reduction in the acid waste process flow would translate to less dilution which will make it more difficult to keep chromium concentrations within operating limits. This could increase sulfur dioxide emission concentrations from the acid waste process. Costs for rerouting this line would include testing, repiping, and permit modifications. However, there may be a cost benefit to reducing the volume of fluids processed.

Option 4: Combination of Above Options

The only combination that is worthy of consideration is an operational modifications plan with a treatment device to remove the food source, mainly GAC adsorption or UV oxidation. It is expected that the treatment devices would keep the hydrocarbon concentration low enough that an odor problem would be extremely rare. The operational modifications plan would act as an additional preventative measure.

Cost Summary

Table 2 summarizes the costs involved with some of the above control methods. Capital costs given only include expenses incurred to purchase the given technology. Additional costs due to construction, repiping, and other process modifications are not included. It is a good possibility that to treat the soluble line effluent with a GAC reactor, UV irradiation reactor, or biofilter would require a building addition. An addition for the GAC reactor would cost about \$25,000.

Table 2. Summary of Treatment Methods to Control the Growth of Sulfate-Reducing Bacteria.

Treatment	Treatment Line	Annual Cost (\$K)	Capital Cost (\$K)	Remarks
Reroute soluble oil effluent	soluble oil effluent	3	0	recommended if allowable
Granular Activated Carbon	soluble oil effluent	9	30	cost dependent upon organic loading
UV Oxidation	soluble oil effluent	1	not known	waiting for capital cost estimate
Biofilter	soluble oil effluent	<1	30-40	difficult to operate and maintain
Quaternary Ammonium Biocide	soluble oil effluent	188	<5	cost estimate is based on retail quantities, bulk cost expected to be less.
Calcium Nitrate	combined lines	15	<5	high potential to succeed

6. Minimizing Sulfur Dioxide Emissions

As stated earlier, a modification to the existing permit has been accepted and there is no longer any regulatory pressure or incentive to reduce the sulfur dioxide emissions from the acid waste treatment process. The apparent solution was to increase the allowable emission rates and to improve the pollutant dispersion by raising the stacks to 35 feet above ground. However, it is consistent with Department of Defense ideals to practice pollution prevention. For this reason, several pollution prevention type suggestions for minimizing sulfur dioxide emissions will be considered below.

Option 1: Installation of Process Controls

With the manual nature of sulfur dioxide addition to the process line, it can be expected that an excess amount of sulfur dioxide will be added. Figure 2 shows how the estimated levels of sulfonation can vary greatly between operators. The values on this figure are only gross estimates based on casual conversations with workers and should not be used for sulfonator input calculations nor should the workers be held responsible. They are only used to illustrate that process controls may significantly regulate sulfur dioxide input to correct levels for proper treatment and minimize emissions. Process controls may also help regulate pH of influent at the optimum target pH of 2.5 where maximum utilization of sulfur dioxide will occur. Process controls are currently being implemented.

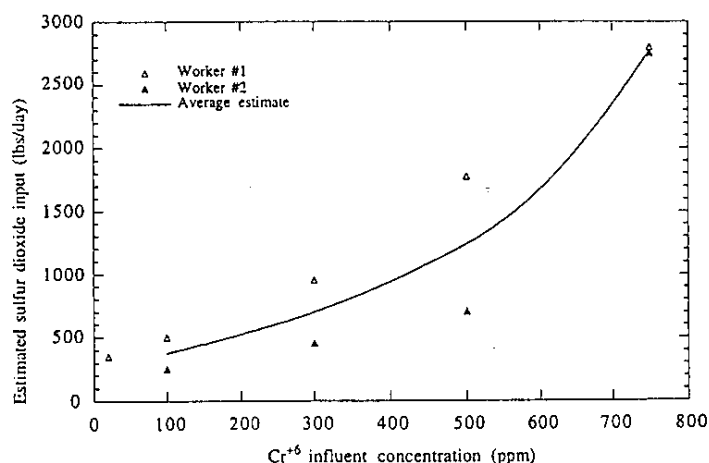


Figure 2. Estimated sulfonation vs. influent hexavalent chromium concentration.

Option 2: Process/Operational Modifications

Managed Dilution

It is interesting to note the upwards direction of the curve in figure 2. As the chromium concentration increases, sulfur dioxide input must be increased to assure complete reduction. However, the solution can absorb a limited amount of sulfur dioxide making it difficult to provide high enough concentrations to treat high chromium concentrations. The increased slope of the curve in figure 2 at about 500 ppm of chromium indicates that a saturation condition is being approached. This translates to a higher ratio of sulfur dioxide input to chromium concentration at higher concentrations. Sulfur dioxide not absorbed or involved in a chemical reaction is desorbed to be emitted. Limiting the hexavalent chromium concentration to a preset level (say 500 ppm) will reduce emissions by avoiding the conditions of high sulfur dioxide desorption. Diverting high chromium concentrations to storage and slowly processing with dilution is a way of achieving this. Currently, this is part of the operations. However, it is likely that improvements could be made.

Pretreatment

It is possible that high chromium concentration influents could be pretreated by routing through an additional sulfur dioxide injection process step. This is only a conceptual idea at this point and would need further consideration and development.

Option 3: Pollution Prevention at Source

Ultimately, practicing pollution prevention by reducing the amount of chromic acid waste generated at the chromium electroplating operations would decrease the sulfur dioxide requirements of the wastewater treatment plant. As an example, installing air pollution control devices that reduce scrubber wastewater and recycle the chromic acid would be an excellent act of pollution prevention.

Option 4: Combination of Options

Any combination of the above options should be considered.

7. Recommendations

In general, the most recommended option for solving the hydrogen sulfide problem is to remove the bacteria's food source. As discussed, the three methods are to divert the soluble oil process effluent away from the acid receiving well, use GAC for adsorbing the hydrocarbons in this effluent, and to destroy the hydrocarbons utilizing UV radiation. It is recommended that any or all three of these very good methods be pursued further. Detailed implementation plans would need to be developed to ensure success. An analysis of potential problems for each of these options would need to be performed. For example, it would need to be determined whether the soluble oil effluent could be discharged to the river, what construction, if any, needs to be performed, if any permits would need to be changed, and other pertinent information. Similarly, methods for implementing the two oxidation technologies would require investigations concerning space allocations, maintenance requirements, influent capacities, effluent concentration, and other information. In the meantime, an operational modification plan could be quickly developed and applied to help control the odors.

The recommendation concerning the sulfur dioxide emissions is to allow current modifications to the plant take place, mainly the process automation and the stack extensions. The process automation has good potential to limit excess sulfur dioxide treatment and the stack height increases remove any potential hazardous conditions (defined by New York State) from nearby properties. Due to the recent permit approval, the cost associated with an end of pipe control technology will be hard to justify. It is also recommended that a plan for modifications in the operational practices be developed to include influent dilution practice improvements and/or a influent pretreatment method.

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- U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM), *Air Pollution Management Study, No. 42-EK- 4457-96, Phase I, Industrial Wastewater Treatment Plant Watervliet Arsenal, Watervliet, New York, 8-12 December 1995*, December 1995.
- USACHPPM, *Final Report Air Pollution Management Study, No. 42-EK-4457-96 Industrial Wastewater Treatment Plant Watervliet Arsenal, Watervliet, New York, 28 February 1996*, April 1996.

REPLY TO
ATTENTION OFDEPARTMENT OF THE ARMY
U.S. ARMY CENTER FOR HEALTH PROMOTION AND PREVENTIVE MEDICINE
ABERDEEN PROVING GROUND, MARYLAND 21010-5422DANA LEVY
SIOWV-ISH
16 APRIL 1996

MCHB-DC-EAP (40)

3 April 1996

MEMORANDUM FOR Commander, U.S. Army Construction Engineering
Research Laboratory, ATTN: CECER-EPD
(Dr. J. Hay), Champaign, IL 61820-1305SUBJECT: Final Report, Air Pollution Management Study
No. 42-EK-4457-96, Industrial Wastewater Treatment Plant,
Watervliet Arsenal, Watervliet, New York, 28 February 1996

1. Five copies of subject report are enclosed.
2. The points of contact are Mr. Albert Merrill or the undersigned, DSN 584-3500/3954 or commercial (410) 671-3500/3954.

FOR THE COMMANDER:

Encl

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Program Manager
Air Pollution Source Management

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USACHPPM

U.S. Army Center for Health Promotion and Preventive Medicine



FINAL REPORT
AIR POLLUTION MANAGEMENT STUDY, NO. 42-EK-4457-96
INDUSTRIAL WASTEWATER TREATMENT PLANT, WATERVLIET ARSENAL
WATERVLIET, NEW YORK
28 FEBRUARY 1996

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U.S. ARMY CENTER FOR HEALTH PROMOTION AND PREVENTIVE MEDICINE

The U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM) lineage can be traced back over a half century to the Army Industrial Hygiene Laboratory which was established at the beginning of World War II under the direct jurisdiction of The Army Surgeon General. It was originally located at the Johns Hopkins School of Hygiene and Public Health with a staff of three and an annual budget not to exceed three thousand dollars. Its mission was to conduct occupational health surveys of Army-operated industrial plants, arsenals, and depots. These surveys were aimed at identifying and eliminating occupational health hazards within the Department of Defense's (DOD) industrial production base and proved to be extremely beneficial to the Nation's war effort.

Most recently, the organization has been nationally and internationally known as the U.S. Army Environmental Hygiene Agency (AEHA) and is located on the Edgewood area of Aberdeen Proving Ground, Maryland. Its mission had been expanded to support the worldwide preventive medicine programs of the Army, DOD and other Federal agencies through consultations, supportive services, investigations and training.

On 1 August 1994, the organization was officially redesignated the U.S. Army Center for Health Promotion and Preventive Medicine and is affectionately referred to as the CHPPM. As always, our mission focus is centered upon the Army Imperatives to that we are optimizing soldier effectiveness by minimizing health risk. The CHPPM's mission is to provide worldwide scientific expertise and services in the areas of:

- Clinical and field preventive medicine
- Environmental and occupational health
- Health promotion and wellness
- Epidemiology and disease surveillance
- Related laboratory services

The Center's quest has always been one of customer satisfaction, technical excellence and continuous quality improvement. Our vision is to be a world-class center of excellence for enhancing military readiness by integrating health promotion and preventive medicine into America's Army. To achieve that end, CHPPM holds everfast to its core values which are steeped in our rich heritage:

- Integrity is our foundation
- Excellence is our standard
- Customer satisfaction is our focus
- Our people are our most valuable resource
- Continuous quality improvement is our pathway

Once again, the organization stands on the threshold of even greater challenges and responsibilities. The CHPPM structure has been reengineered to include General Officer leadership in order to support the Army of the future. The professional disciplines represented at the Center have been expanded to include a wide array of medical, scientific, engineering, and administrative support personnel.

As the CHPPM moves into the next century, we are an organization fiercely proud of our history, yet equally excited about the future. The Center is destined to continue its development as a world-class organization with expanded preventive health care services provided to the Army, DOD, other Federal agencies, the Nation, and the world community.



REPLY TO
ATTENTION OF

MCHB-DC-EAP

DEPARTMENT OF THE ARMY
U.S. ARMY CENTER FOR HEALTH PROMOTION AND PREVENTIVE MEDICINE
ABERDEEN PROVING GROUND, MARYLAND 21010-5422

FINAL REPORT
AIR POLLUTION MANAGEMENT STUDY, NO. 42-EK-4457-96
INDUSTRIAL WASTEWATER TREATMENT PLANT, WATERVLIET ARSENAL
WATERVLIET, NEW YORK
28 FEBRUARY 1996

1. REFERENCE. Memorandum, USACHPPM, MCHB-DE-AP, 1 March 1996, subject: Air Pollution Management Study, No. 42-EK-4457-96, Phase I, Industrial Wastewater Treatment Plant, Watervliet Arsenal, Watervliet, New York, 8-12 December 1995.

2. PURPOSE. The purpose of this study was to determine the emissions of sulfur dioxide (SO_2) from the reaction tank at the industrial wastewater treatment plant (IWTP) during periods of varying hexavalent chrome (Cr^{+6}) concentration in the influent wastestream.

3. GENERAL.

a. Background. The IWTP treats chromic acid waste from a chrome (Cr) plating operation. As waste enters the plant, SO_2 gas is injected into the wastestream to reduce the Cr^{+6} to the less toxic trivalent species. In general, higher concentrations of Cr^{+6} require more SO_2 to successfully treat the waste. The addition of SO_2 to the wastestream is governed by the color of the influent wastestream. Waste with a high Cr^{+6} concentration has a yellow color while lesser concentrations have a green-blue color. Plant operators adjust the SO_2 input valve (sulfonator) until the wastestream exhibits the color they know to correspond to proper reduction of the waste.

b. Previous Test. Previous testing (see reference) indicated that when the IWTP is treating waste with nominal concentrations of Cr^{+6} (i.e., 250 ppm Cr), SO_2 emissions from the reaction tank are low (0.02 lb/hr). A range of operating conditions was not tested due to various problems.

c. Sampling and Analysis Procedures.

(1) Simulated Conditions. Quantities of chromic acid waste with a high Cr^{+6} concentration were dumped into the system

Readiness thru Health

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at the plating facility. The waste takes approximately 12 minutes to reach the IWTP.

(2) Sampling.

(a) SO₂ Measurements. Sampling began as the first batch of waste was dumped into the system at the plating facility. Testing continued for approximately 3 hours while two more batches were dumped into the system. Each batch was approximately 10-15 gallons.

(b) Velocity Measurements. Velocity was measured after the sampling probe was removed from the stack.

(3) Equipment.

(a) SO₂ Measurements. A COSA® 6000 CD meter was used to detect SO₂ in stack gas. The COSA 6000 meter has an internal sample pump and detects SO₂ with a wet chemical cell. The COSA 6000 meter has the capability to detect SO₂ in the range 0-4000 ppm with a sensitivity of 1.0 ppm and accurate to ±2% of the reading. The calibration of the COSA 6000 meter was checked before and after the test with gases in concentrations of 0 and 241 ppm SO₂. The COSA 6000 meter is not susceptible to interference from any other sulfur compounds except hydrogen sulfide (H₂S). Approximately, 80% of any H₂S present in the gas sample will be read by the monitor as SO₂.

(b) Velocity Measurements. Velocity measurements were taken by measuring the pressure head with a standard pitot tube and manometer.

d. Sampling Location.

(1) SO₂ Measurements. A gas sample was extracted from a hole in the exhaust vent of reaction tank No. 2, approximately 2 ½ feet above the tank top.

(2) Velocity Measurements. Exhaust gas velocity measurements were made from the same location.

COSA® is a registered trademark of COSA Instruments Corp., Norwood, New Jersey. Use of trademarked names does not imply endorsement by the U.S. Army but is intended only to assist in identification of a specific product.

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e. Assessment Personnel. Appendix A is a list of personnel who participated in this study.

4. FINDINGS AND DISCUSSION.

a. Test Summary. The Table is a summary of the testing plan, concentrations detected and emissions rates.

b. Data Summary. Appendix B includes all test data recorded.

c. Emissions. SO₂ emissions averaged 82 ppm (0.5 lb/hr). The maximum emission rate was 205 ppm (1.25 lb/hr).

d. Velocity Measurements. Flow rate was calculated from the measured pressure head. Flow rate and measured velocities are presented in the table.

5. CONCLUSIONS. SO₂ emissions from the reaction tank increase during periods when the IWTP is receiving chromic acid waste with high concentrations of Cr⁶⁺.

TABLE. SAMPLING AND DATA SUMMARY.

Sulfonator Setting	*
Cr ⁶⁺ Concentration at 9:58 AM (ppm)	750
Reaction Tank	
Gas Velocity (ft/sec)	29.8
Flow Rate (dscf/hr)	36601.0
SO ₂ Concentration (ppm)	
Average †	82.6
Maximum	205.0
SO ₂ Emission Rate (lb/hr)	
Average †	0.5
Maximum	1.2

* Sulfonator setting changed according to operating parameters. See Appendix B for details.

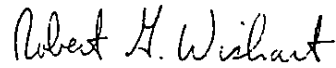
† Over 2-hour test duration.

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6. RECOMMENDATION. Use the data to assess the need for emissions controls.


ALBERT L. MERRILL
Environmental Engineer
Air Pollution Source Management
Program

REVIEWED BY:


ROBERT G. WISHART
Supervisory Mechanical Engineer
Air Pollution Source Management
Program

APPROVED BY:


DAVID L. DAUGHRILL
Program Manager
Air Pollution Source Management

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APPENDIX A
ASSESSMENT PERSONNEL

1. IWTP, Watervliet Arsenal
Brian Merrell - IWTP Operator.
2. USACHPPM
Albert L. Merrill - Project Officer
3. USACERL
Dr. James Hay - Project Engineer

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APPENDIX B

TEST DATA

B-1

WVADATA

				82.58772	ppm /SO2 during continuous test		
					test 8:02 - 9:57		
				205	Max		
Assume	528	deg R stack temp			point	prs hd	sqrt prs hd
	0.85	% moisture	0.0085		1	0.17	0.412311
					2	0.2	0.447214
Static Pressure		-0.31	in h2o		3	0.21	0.458258
Stack area		0.348889	sq ft		4	0.21	0.458258
P bar		29.5	in Hg		5	0.2	0.447214
					6	0.19	0.43589
					7	0.19	0.43589
						0.195714	0.442148
stack pressure	29.47721	in Hg					
stack gas mw	28.74865						
stack gas vel	29.83299	ft/s					
gas flow rate	36601.68	dscf/hr					
emission rate avg	0.502108	lb/hr					
emission rate max	1.246338	lb/hr					

WWADATA

30	8:34:24	02.28.199	20.9	12	34	0	49.6	62.2			
31	8:35:24	02.28.199	20.9	15	42	0	49.4	62.4			
32	8:36:25	02.28.199	20.9	18	51	0	50.1	62.6			
33	8:37:24	02.28.199	20.9	21	60	0	50.1	62.6			
34	8:38:24	02.28.199	20.9	24	68	0	50.7	62.7			
35	8:39:24	02.28.199	20.9	27	77	0	50.7	62.9			
36	8:40:24	02.28.199	20.9	30	85	0	51.2	62.9			
37	8:41:24	02.28.199	20.9	32	91	0	51.4	63.1			
38	8:42:24	02.28.199	20.9	34	97	0	51.4	63.3			
39	8:43:24	02.28.199	20.9	34	97	0	51.9	63.3			
40	8:44:25	02.28.199	20.9	35	100	0	52.1	63.5			
41	8:45:24	02.28.199	20.9	36	102	0	52.8	63.6			
42	8:46:24	02.28.199	20.9	37	105	0	52.5	63.6			
43	8:47:24	02.28.199	20.9	38	108	0	53.4	63.8			
44	8:48:24	02.28.199	20.9	41	117	0	53.6	64.0			
45	8:49:24	02.28.199	20.9	44	125	0	53.4	64.0			
46	8:50:24	02.28.199	20.9	44	125	0	53.7	64.2			
47	8:51:24	02.28.199	20.9	44	125	0	54.1	66.3			
48	8:52:24	02.28.199	20.9	43	122	0	54.5	67.6			
49	8:53:24	02.28.199	20.9	43	122	0	54.6	68.3			
50	8:54:24	02.28.199	20.9	44	125	0	55.0	69.0			
51	8:55:25	02.28.199	20.9	46	131	0	55.0	69.4			
52	8:56:24	02.28.199	20.9	46	131	0	55.9	69.6			
53	8:57:24	02.28.199	20.9	47	134	0	56.1	69.6	sulfonator to 90%		
54	8:58:24	02.28.199	20.9	46	131	0	56.6	69.6	adds No 2 sulfonator		
55	8:59:24	02.28.199	20.9	45	128	0	56.8	69.8	total flow of 1600 lb/24hrs		
56	9:00:24	02.28.199	20.9	45	128	0	57.0	69.8			
57	9:01:24	02.28.199	20.9	48	137	0	57.7	69.8			
58	9:02:24	02.28.199	20.9	55	157	0	57.5	69.9			
59	9:03:25	02.28.199	20.9	64	182	0	58.4	69.8			
60	9:04:24	02.28.199	20.9	74	211	0	58.1	69.9			
61	9:05:24	02.28.199	20.9	75	214	0	58.1	69.9			
62	9:06:24	02.28.199	20.9	80	228	0	58.2	70.1			
63	9:07:24	02.28.199	20.9	86	245	0	58.4	70.1			
64	9:08:24	02.28.199	20.9	100	285	0	59.0	69.9			

WWADATA

65	9:09:24	02.28.199	20.9	102	291	0	59.1	70.1			
66	9:10:25	02.28.199	20.9	105	300	0	59.7	69.9			
67	9:11:24	02.28.199	20.9	109	311	0	59.3	69.9			
68	9:12:24	02.28.199	20.9	109	311	0	59.9	69.9			
69	9:13:24	02.28.199	20.9	120	343	0	60.0	70.1			
70	9:14:24	02.28.199	20.9	122	348	0	60.2	69.9			
71	9:15:24	02.28.199	20.9	124	354	0	60.6	69.9			
72	9:16:25	02.28.199	20.9	128	355	0	60.8	70.1			
73	9:17:24	02.28.199	20.9	136	388	0	61.3	70.1			
74	9:18:24	02.28.199	20.9	154	440	0	60.9	70.1			
75	9:19:24	02.28.199	20.9	156	446	0	61.7	69.9			
76	9:20:24	02.28.199	20.9	163	466	0	61.3	70.1			
77	9:21:25	02.28.199	20.9	169	483	0	61.8	69.9			
78	9:22:24	02.28.199	20.9	169	483	0	61.8	70.1			
79	9:23:24	02.28.199	20.9	153	437	0	62.2	70.1			
80	9:24:24	02.28.199	20.9	144	411	0	63.1	70.1			
81	9:25:25	02.28.199	20.9	142	405	0	62.9	70.1			
82	9:26:24	02.28.199	20.9	141	403	0	63.5	70.3			
83	9:27:24	02.28.199	20.9	142	405	0	62.9	70.3			
84	9:28:24	02.28.199	20.9	143	408	0	63.6	70.3			
85	9:29:24	02.28.199	20.9	142	405	0	63.6	70.3			
86	9:30:25	02.28.199	20.9	155	443	0	63.8	70.3			
87	9:31:25	02.28.199	20.9	167	477	0	63.8	70.5			
88	9:32:24	02.28.199	20.9	169	483	0	63.8	70.3			
89	9:33:24	02.28.199	20.9	170	486	0	64.9	70.3			
90	9:34:24	02.28.199	20.9	169	483	0	64.2	70.3			
91	9:35:24	02.28.199	20.9	172	491	0	65.1	70.1			
92	9:36:24	02.28.199	20.9	161	460	0	64.2	70.3			
93	9:37:25	02.28.199	20.9	153	437	0	65.1	70.1			
94	9:38:25	02.28.199	20.9	158	451	0	64.7	70.3			
95	9:39:24	02.28.199	20.9	164	468	0	65.8	70.1			
96	9:40:24	02.28.199	20.9	168	480	0	65.4	70.3			
97	9:41:24	02.28.199	20.9	164	468	0	65.3	70.5			
98	9:42:24	02.28.199	20.9	173	494	0	66.0	70.3			
99	9:43:24	02.28.199	20.9	182	520	0	65.4	70.5			

WVADATA

100	9:44:25	02.28.199	20.9	195	557	0	65.4	70.7			
101	9:45:25	02.28.199	20.9	186	531	0	65.4	71.0			
102	9:46:24	02.28.199	20.9	175	500	0	69.9	71.6			
103	9:47:24	02.28.199	20.9	193	551	0	70.5	71.9			
104	9:48:24	02.28.199	20.9	187	534	0	70.7	72.3			
105	9:49:24	02.28.199	20.9	181	517	0	72.3	72.6			
106	9:50:25	02.28.199	20.9	178	508	0	72.8	73.0			
107	9:51:25	02.28.199	20.9	184	526	0	72.8	73.2			
108	9:52:24	02.28.199	20.9	185	528	0	73.7	73.5			
109	9:53:24	02.28.199	20.9	195	557	0	73.4	73.5			
110	9:54:24	02.28.199	20.9	190	543	0	73.5	73.7			
111	9:55:24	02.28.199	20.9	193	551	0	73.0	73.7			
112	9:56:25	02.28.199	20.9	203	580	0	72.8	73.9			
113	9:57:24	02.28.199	20.9	205	586	0	71.9	74.1			
114	9:58:24	02.28.199	20.9	188	537	0	69.9	74.1			
115	9:59:24	02.28.199	20.9	101	288	0	67.1	74.3			
116	10:00:25	02.28.199	20.9	67	191	0	65.6	74.3			
117	10:01:24	02.28.199	20.9	53	151	0	64.7	74.4			
118	10:02:24	02.28.199	20.9	44	125	0	64.0	74.4			
119	10:03:25	02.28.199	20.9	37	105	0	63.5	74.4			
120	10:04:24	02.28.199	20.9	33	94	0	62.9	74.4			
121	10:05:24	02.28.199	20.9	30	85	0	62.6	74.6			
122	10:06:24	02.28.199	20.9	27	77	0	62.2	74.8			
123	10:07:24	02.28.199	20.9	25	71	0	61.8	74.8			
124	10:08:25	02.28.199	20.9	23	65	0	61.7	74.8			
125	10:09:24	02.28.199	20.9	21	60	0	61.7	74.8			
126	10:10:24	02.28.199	20.9	20	57	0	61.5	74.8			
127	10:11:24	02.28.199	20.9	19	54	0	61.7	75.0			
128	10:12:25	02.28.199	20.9	18	51	0	61.5	75.0			
129	10:13:25	02.28.199	20.9	17	48	0	61.7	75.2			
130	10:14:24	02.28.199	20.9	17	48	0	61.7	75.2			
131	10:15:24	02.28.199	20.9	16	45	0	61.7	75.2			
132	10:16:25	02.28.199	20.9	15	42	0	61.7	75.2			
133	10:17:25	02.28.199	20.9	15	42	0	60.4	59.9			
134	10:18:01	02.28.199	20.9	14	40	0	59.1	66.9			

WVADATA

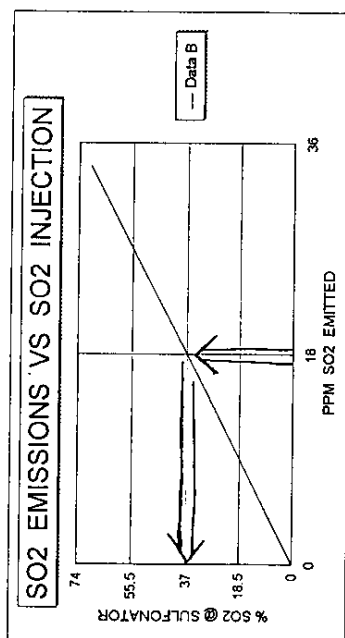
135	10:19:01	02.28.199	20.9	13	37	0	58.6	63.6		
136	10:20:00	02.28.199	20.9	13	37	0	59.1	61.8		
137	10:21:00	02.28.199	20.9	12	34	0	58.6	60.2		
138	10:22:00	02.28.199	20.9	11	31	0	58.6	60.9		
139	10:23:00	02.28.199	20.9	10	28	0	58.8	61.5		
140	10:24:00	02.28.199	20.9	9	25	0	58.8	61.8		
141	10:25:00	02.28.199	20.9	9	25	0	58.8	61.8		
142	10:26:00	02.28.199	20.9	8	22	0	59.0	61.8		
143	10:27:01	02.28.199	20.9	8	22	0	59.0	61.7		
144	10:28:01	02.28.199	20.9	8	22	0	58.6	69.6		
145	10:29:00	02.28.199	20.9	7	20	0	58.2	62.0		
146	10:30:00	02.28.199	20.9	7	20	0	57.7	61.1		
147	10:31:00	02.28.199	20.9	7	20	0	57.5	59.5		
148	10:32:00	02.28.199	20.9	7	20	0	56.8	58.4		
149	10:33:00	02.28.199	20.9	7	20	0	57.0	58.4		
150	10:34:00	02.28.199	20.9	6	17	0	57.7	58.6		
151	10:35:00	02.28.199	20.9	6	17	0	59.0	58.4		
152	10:36:00	02.28.199	20.9	5	14	0	59.5	58.6		
153	10:37:00	02.28.199	20.9	5	14	0	59.9	58.2		
154	10:38:00	02.28.199	20.9	4	11	0	60.4	58.4		
155	10:39:00	02.28.199	20.9	4	11	0	60.8	58.6		
156	10:40:00	02.28.199	20.9	4	11	0	61.3	58.4		
157	10:41:00	02.28.199	20.9	4	11	0	61.8	58.4		
158	10:42:00	02.28.199	20.9	3	8	0	62.4	58.2		
159	10:43:00	02.28.199	20.9	3	8	0	62.4	58.4		
160	10:44:00	02.28.199	20.9	2	5	0	62.7	58.1		
161	10:45:00	02.28.199	20.9	2	5	0	63.1	58.1		
162	10:46:00	02.28.199	20.9	2	5	0	63.1	57.2		
163	10:47:00	02.28.199	20.9	1	2	0	58.2	56.8	probe returned to reaction tankl	
164	10:48:00	02.28.199	20.9	3	8	0	59.5	57.3		
165	10:49:00	02.28.199	20.9	5	14	0	60.4	57.2		
166	10:50:00	02.28.199	20.9	7	20	0	60.6	56.6		
167	10:51:00	02.28.199	20.9	10	28	0	60.9	56.4		
168	10:52:00	02.28.199	20.9	12	34	0	60.9	57.0		
169	10:53:00	02.28.199	20.9	14	40	0	61.5	57.3		

WVADATA

170	10:54:00	02.28.199	20.9	16	45	0	60.9	59.0		
171	10:55:01	02.28.199	20.9	18	51	0	60.2	59.9		
172	10:56:00	02.28.199	20.9	19	54	0	60.0	60.8		
173	10:57:00	02.28.199	20.9	20	57	0	59.7	60.2		
174	10:58:00	02.28.199	20.9	20	57	0	59.5	60.9		
175	10:59:01	02.28.199	20.9	20	57	0	61.1	61.8		
176	11:00:00	02.28.199	20.9	19	54	0	58.4	62.7	probe removed	
177	11:01:00	02.28.199	20.9	17	48	0	57.2	63.3	pulling ambient	
178	11:02:00	02.28.199	20.9	16	45	0	56.1	63.6		
179	11:03:01	02.28.199	20.9	15	42	0	55.4	63.1		
180	11:04:00	02.28.199	20.9	14	40	0	54.8	63.3		
181	11:05:00	02.28.199	20.9	13	37	0	54.5	63.5		
182	11:06:00	02.28.199	20.9	12	34	0	54.1	64.7		
183	11:07:00	02.28.199	20.9	12	34	0	54.1	64.2		
184	11:08:01	02.28.199	20.9	11	31	0	54.1	63.1		
185	11:09:00	02.28.199	20.9	11	31	0	53.9	63.8		
186	11:10:00	02.28.199	20.9	10	28	0	55.7	64.9		
187	11:11:00	02.28.199	20.9	10	28	0	55.0	65.1	0	
188	11:12:00	02.28.199	20.9	9	25	0	55.5	65.4		
189	11:13:01	02.28.199	20.9	8	22	0	56.1	65.6		
190	11:14:00	02.28.199	20.9	7	20	0	56.8	64.9		
191	11:15:00	02.28.199	20.9	7	20	0	57.7	65.3		
192	11:16:00	02.28.199	20.9	6	17	0	58.2	64.2		
				82.58772	ppm /SO2 during continuous testing of reaction tank 2					
				test 8:02 - 9:57						
				205	Max					
Assume	528 deg R stack temp 0.85% moisture		0.0085	point	prs hd		sqrt prs hd			
					1	0.17	0.412311			
Static Pressure					2		0.447214			
					3		0.21 0.458258			
Stack area		-0.31 in h2o 0.348889 sq ft			4		0.21 0.458258			
					5		0.2 0.447214			
P bar		29.5 in Hg			6		0.19 0.43589			
					7		0.19 0.43589			

SULFUR DIOXIDE EMISSIONS AT REACTION TANK #2 AT IWTP. BASED ON DATA FROM CHPPM. DATA NOT VALIDATED YET. 29 FEBRUARY 1996. *Dana L. Levy* 29 Feb 96

time	ppm emitted	percent SO2
zero	0	0
08:40	30	70
08:41	32	70
08:42	34	70
08:43	34	70
08:44	35	70
08:45	36	70
08:46	37	70
08:47	38	70
08:48	41	70
08:49	44	70
08:50	44	70
08:51	44	70
08:52	43	70
08:53	43	70
08:54	44	70
08:55	46	70
08:56	46	70
10:54	16	70
10:55	18	70
10:56	19	70
10:57	20	70
10:58	20	70
10:59	20	70
average	34	70
zero	0	0



NOTE: ON AVERAGE, 70% SULFUR DIOXIDE (I.E., 70 % OF ONE SULFONATOR, ZERO OPERATION OF THE OTHER SULFONATOR) RESULTS IN EMISSION OF 34 PPM SO2.

THEREFORE, TO STAY BELOW THE MAGIC AMOUNT 18 PPM SO2, MUST KEEP SULFONATOR OPERATION BELOW 37% SULFUR DIOXIDE (I.E., 37% OF ONE SULFONATOR, ZERO OPERATION OF THE OTHER SULFONATOR).

FOR PURPOSE OF DISCUSSION, 200% SO2 IS REFERENCED AS HAVING BOTH SULFONATORS OPERATING AT MAXIMUM CAPACITY SIMULTANEOUSLY.

THE IWTP INDICATES 100% (I.E., FULL CAPACITY OF ONE SULFONATOR, ZERO OPERATION OF THE OTHER SULFONATOR) EQUATES TO 1,900 POUNDS SO2 PER 24 HOUR PERIOD. THEREFORE, 37% EQUATES TO 700 POUNDS SO2 PER 24 HOUR PERIOD. THE IWTP HAS BEEN INSTRUCTED (NEW SOP EFFECTIVE IMMEDIATELY) NEVER OPERATE ABOVE 700 POUNDS SO2 PER 24 HOUR PERIOD.

WVADATA

32	8:36:25	02.28.1996	20.9	18	51	0	50.1	62.6				
33	8:37:24	02.28.1996	20.9	21	60	0	50.1	62.6				
34	8:38:24	02.28.1996	20.9	24	68	0	50.7	62.7				
35	8:39:24	02.28.1996	20.9	27	77	0	50.7	62.9				
36	8:40:24	02.28.1996	20.9	30	85	0	51.2	62.9				
37	8:41:24	02.28.1996	20.9	32	91	0	51.4	63.1				
38	8:42:24	02.28.1996	20.9	34	97	0	51.4	63.3				
39	8:43:24	02.28.1996	20.9	34	97	0	51.9	63.3				
40	8:44:25	02.28.1996	20.9	35	100	0	52.1	63.5				
41	8:45:24	02.28.1996	20.9	36	102	0	52.8	63.6				
42	8:46:24	02.28.1996	20.9	37	105	0	52.5	63.6				
43	8:47:24	02.28.1996	20.9	38	108	0	53.4	63.8				
44	8:48:24	02.28.1996	20.9	41	117	0	53.6	64.0				
45	8:49:24	02.28.1996	20.9	44	125	0	53.4	64.0				
46	8:50:24	02.28.1996	20.9	44	125	0	53.7	64.2				
47	8:51:24	02.28.1996	20.9	44	125	0	54.1	66.3				
48	8:52:24	02.28.1996	20.9	43	122	0	54.5	67.6				
49	8:53:24	02.28.1996	20.9	43	122	0	54.6	68.3				
50	8:54:24	02.28.1996	20.9	44	125	0	55.0	69.0				
51	8:55:25	02.28.1996	20.9	46	131	0	55.0	69.4				
52	8:56:24	02.28.1996	20.9	46	131	0	55.9	69.6				
53	8:57:24	02.28.1996	20.9	47	134	0	56.1	69.6				
54	8:58:24	02.28.1996	20.9	46	131	0	56.6	69.6				
55	8:59:24	02.28.1996	20.9	45	128	0	56.8	69.8				
56	9:00:24	02.28.1996	20.9	45	128	0	57.0	69.8				
57	9:01:24	02.28.1996	20.9	48	137	0	57.7	69.8				
58	9:02:24	02.28.1996	20.9	55	157	0	57.5	69.9				
59	9:03:25	02.28.1996	20.9	64	182	0	58.4	69.8				
60	9:04:24	02.28.1996	20.9	74	211	0	58.1	69.9				
61	9:05:24	02.28.1996	20.9	75	214	0	58.1	69.9				
62	9:06:24	02.28.1996	20.9	80	228	0	58.2	70.1				
63	9:07:24	02.28.1996	20.9	86	245	0	58.4	70.1				
64	9:08:24	02.28.1996	20.9	100	285	0	59.0	69.9				
65	9:09:24	02.28.1996	20.9	102	291	0	59.1	70.1				
66	9:10:25	02.28.1996	20.9	105	300	0	59.7	69.9				
67	9:11:24	02.28.1996	20.9	109	311	0	59.3	69.9				
68	9:12:24	02.28.1996	20.9	109	311	0	59.9	69.9				

sulfonator to 90%
adds No 2 sulfonator
total flow of 1600 lb/24hrs

WVADATA

69	9:13:24	02.28.1996	20.9	120	343	0	60.0	70.1				
70	9:14:24	02.28.1996	20.9	122	348	0	60.2	69.9				
71	9:15:24	02.28.1996	20.9	124	354	0	60.6	69.9	10-15 gal concentrated Cr dumped into system. 12 min to get to plant.			
72	9:16:25	02.28.1996	20.9	128	365	0	60.8	70.1				
73	9:17:24	02.28.1996	20.9	136	388	0	61.3	70.1				
74	9:18:24	02.28.1996	20.9	154	440	0	60.9	70.1				
75	9:19:24	02.28.1996	20.9	156	446	0	61.7	69.9				
76	9:20:24	02.28.1996	20.9	163	466	0	61.3	70.1				
77	9:21:25	02.28.1996	20.9	169	483	0	61.8	69.9				
78	9:22:24	02.28.1996	20.9	169	483	0	61.8	70.1				
79	9:23:24	02.28.1996	20.9	153	437	0	62.2	70.1				
80	9:24:24	02.28.1996	20.9	144	411	0	63.1	70.1				
81	9:25:25	02.28.1996	20.9	142	405	0	62.9	70.1	sulfonator up to 150%			
82	9:26:24	02.28.1996	20.9	141	403	0	63.5	70.3				
83	9:27:24	02.28.1996	20.9	142	405	0	62.9	70.3				
84	9:28:24	02.28.1996	20.9	143	408	0	63.6	70.3				
85	9:29:24	02.28.1996	20.9	142	405	0	63.6	70.3				
86	9:30:25	02.28.1996	20.9	155	443	0	63.8	70.3	Brian guesses 600 ppm Cr set both sulfonators to max flow = 2800 lb/24			
87	9:31:25	02.28.1996	20.9	167	477	0	63.8	70.5				
88	9:32:24	02.28.1996	20.9	169	483	0	63.8	70.3				
89	9:33:24	02.28.1996	20.9	170	486	0	64.9	70.3				
90	9:34:24	02.28.1996	20.9	169	483	0	64.2	70.3				
91	9:35:24	02.28.1996	20.9	172	491	0	65.1	70.1				
92	9:36:24	02.28.1996	20.9	161	460	0	64.2	70.3				
93	9:37:25	02.28.1996	20.9	153	437	0	65.1	70.1				
94	9:38:25	02.28.1996	20.9	158	451	0	64.7	70.3				
95	9:39:24	02.28.1996	20.9	164	468	0	65.8	70.1				
96	9:40:24	02.28.1996	20.9	168	480	0	65.4	70.3				
97	9:41:24	02.28.1996	20.9	164	468	0	65.3	70.5				
98	9:42:24	02.28.1996	20.9	173	494	0	66.0	70.3				
99	9:43:24	02.28.1996	20.9	182	520	0	65.4	70.5				
100	9:44:25	02.28.1996	20.9	195	557	0	65.4	70.7				
101	9:45:25	02.28.1996	20.9	186	531	0	65.4	71.0				
102	9:46:24	02.28.1996	20.9	175	500	0	69.9	71.6				
103	9:47:24	02.28.1996	20.9	193	551	0	70.5	71.9				
104	9:48:24	02.28.1996	20.9	187	534	0	70.7	72.3				
105	9:49:24	02.28.1996	20.9	181	517	0	72.3	72.6				

WVADATA

106	9:50:25	02.28.1996	20,9	178	508	0	72,8	73,0			
107	9:51:25	02.28.1996	20,9	184	526	0	72,8	73,2			
108	9:52:24	02.28.1996	20,9	185	528	0	73,7	73,5			
109	9:53:24	02.28.1996	20,9	195	557	0	73,4	73,5			
110	9:54:24	02.28.1996	20,9	190	543	0	73,5	73,7			
111	9:55:24	02.28.1996	20,9	183	551	0	73,0	73,7	return to 1 sulfonator at 70%		
112	9:56:25	02.28.1996	20,9	203	580	0	72,8	73,9	=1200 lb/24hrs		
113	9:57:24	02.28.1996	20,9	205	586	0	71,9	74,1	probe removed from stack		
114	9:58:24	02.28.1996	20,9	188	537	0	69,9	74,1	final chrome 750 ppm		
115	9:59:24	02.28.1996	20,9	101	288	0	67,1	74,3	probe in blend tank		
116	10:00:25	02.28.1996	20,9	67	191	0	65,6	74,3	750 ppm		
117	10:01:24	02.28.1996	20,9	53	151	0	64,7	74,4	measured		
118	10:02:24	02.28.1996	20,9	44	125	0	64,0	74,4	VIA		
119	10:03:25	02.28.1996	20,9	37	105	0	63,5	74,4	HACH TEST		
120	10:04:24	02.28.1996	20,9	33	94	0	62,9	74,4			
121	10:05:24	02.28.1996	20,9	30	85	0	62,6	74,6			
122	10:06:24	02.28.1996	20,9	27	77	0	62,2	74,8			
123	10:07:24	02.28.1996	20,9	25	71	0	61,8	74,8			
124	10:08:25	02.28.1996	20,9	23	65	0	61,7	74,8			
125	10:09:24	02.28.1996	20,9	21	60	0	61,7	74,8			
126	10:10:24	02.28.1996	20,9	20	57	0	61,5	74,8			
127	10:11:24	02.28.1996	20,9	19	54	0	61,7	75,0			
128	10:12:25	02.28.1996	20,9	18	51	0	61,5	75,0			
129	10:13:25	02.28.1996	20,9	17	48	0	61,7	75,2			
130	10:14:24	02.28.1996	20,9	17	48	0	61,7	75,2			
131	10:15:24	02.28.1996	20,9	16	45	0	61,7	75,2			
132	10:16:25	02.28.1996	20,9	15	42	0	61,7	75,2			
133	10:17:25	02.28.1996	20,9	15	42	0	60,4	69,9	probe removed pulling ambient sample		
134	10:18:01	02.28.1996	20,9	14	40	0	59,1	66,9			
135	10:19:01	02.28.1996	20,9	13	37	0	58,6	63,6			
136	10:20:00	02.28.1996	20,9	13	37	0	59,1	61,8			
137	10:21:00	02.28.1996	20,9	12	34	0	58,6	60,2			
138	10:22:00	02.28.1996	20,9	11	31	0	58,6	60,9			
139	10:23:00	02.28.1996	20,9	10	28	0	58,8	61,5			
140	10:24:00	02.28.1996	20,9	9	25	0	58,8	61,8			
141	10:25:00	02.28.1996	20,9	9	25	0	58,8	61,8			
142	10:26:00	02.28.1996	20,9	8	22	0	59,0	61,8			

WVADATA

143	10:27:01	02.28.1996	20.9	8	22	0	59.0	61.7				
144	10:28:01	02.28.1996	20.9	8	22	0	58.6	69.6				
145	10:29:00	02.28.1996	20.9	7	20	0	58.2	62.0				
146	10:30:00	02.28.1996	20.9	7	20	0	57.7	61.1				
147	10:31:00	02.28.1996	20.9	7	20	0	57.5	59.5				
148	10:32:00	02.28.1996	20.9	7	20	0	56.8	58.4				
149	10:33:00	02.28.1996	20.9	7	20	0	57.0	58.4				
150	10:34:00	02.28.1996	20.9	6	17	0	57.7	58.6				
151	10:35:00	02.28.1996	20.9	6	17	0	59.0	58.4				
152	10:36:00	02.28.1996	20.9	5	14	0	59.5	58.6				
153	10:37:00	02.28.1996	20.9	5	14	0	59.9	58.2				
154	10:38:00	02.28.1996	20.9	4	11	0	60.4	58.4				
155	10:39:00	02.28.1996	20.9	4	11	0	60.8	58.6				
156	10:40:00	02.28.1996	20.9	4	11	0	61.3	58.4				
157	10:41:00	02.28.1996	20.9	4	11	0	61.8	58.4				
158	10:42:00	02.28.1996	20.9	3	8	0	62.4	58.2				
159	10:43:00	02.28.1996	20.9	3	8	0	62.4	58.4				
160	10:44:00	02.28.1996	20.9	2	5	0	62.7	58.1				
161	10:45:00	02.28.1996	20.9	2	5	0	63.1	58.1				
162	10:46:00	02.28.1996	20.9	2	5	0	63.1	57.2				
163	10:47:00	02.28.1996	20.9	1	2	0	58.2	56.8				
164	10:48:00	02.28.1996	20.9	3	8	0	59.5	57.3				
165	10:49:00	02.28.1996	20.9	5	14	0	60.4	57.2				
166	10:50:00	02.28.1996	20.9	7	20	0	60.6	56.6				
167	10:51:00	02.28.1996	20.9	10	28	0	60.9	56.4				
168	10:52:00	02.28.1996	20.9	12	34	0	60.9	57.0				
169	10:53:00	02.28.1996	20.9	14	40	0	61.5	57.3				
170	10:54:00	02.28.1996	20.9	16	45	0	60.9	59.0				
171	10:55:01	02.28.1996	20.9	18	51	0	60.2	59.9				
172	10:56:00	02.28.1996	20.9	19	54	0	60.0	60.8				
173	10:57:00	02.28.1996	20.9	20	57	0	59.7	60.2				
174	10:58:00	02.28.1996	20.9	20	57	0	59.5	60.9				
175	10:59:01	02.28.1996	20.9	20	57	0	61.1	61.8				
176	11:00:00	02.28.1996	20.9	19	54	0	58.4	62.7				
177	11:01:00	02.28.1996	20.9	17	48	0	57.2	63.3				
178	11:02:00	02.28.1996	20.9	16	45	0	56.1	63.6				
179	11:03:01	02.28.1996	20.9	15	42	0	55.4	63.1				

probe returned to reaction tank

probe removed
pulling ambient

WVADATA

180	11:04:00	02.28.1996	20.9	14	40	0	54.8	63.3		
181	11:05:00	02.28.1996	20.9	13	37	0	54.5	63.5		
182	11:06:00	02.28.1996	20.9	12	34	0	54.1	64.7		
183	11:07:00	02.28.1996	20.9	12	34	0	54.1	64.2		
184	11:08:01	02.28.1996	20.9	11	31	0	54.1	63.1		
185	11:09:00	02.28.1996	20.9	11	31	0	53.9	63.8		
186	11:10:00	02.28.1996	20.9	10	28	0	55.7	64.9		
187	11:11:00	02.28.1996	20.9	10	28	0	55.0	65.1	0	
188	11:12:00	02.28.1996	20.9	9	25	0	55.5	65.4		
189	11:13:01	02.28.1996	20.9	8	22	0	56.1	65.6		
190	11:14:00	02.28.1996	20.9	7	20	0	56.8	64.9		
191	11:15:00	02.28.1996	20.9	7	20	0	57.7	65.3		
192	11:16:00	02.28.1996	20.9	6	17	0	58.2	64.2		
				82.58772 ppm /SO2 during continuous testing of reaction tank 2						
				test 8:02 - 9:57						
				205						
Assume	deg R	stack temp			point	prs hd	sqrt prs hd			
	% moisture		0.0085		1	0.17	0.412311			
					2	0.2	0.447214			
Static Pressure		-0.31 in h2o			3	0.21	0.458258			
Stack area		1.395556 sq ft			4	0.21	0.458258			
P bar		29.5 in Hg			5	0.2	0.447214			
					6	0.19	0.43589			
					7	0.19	0.43589			
						0.195714	0.442148			
stack press	29.47721	in Hg								
stack gas r	28.74865									
stack gas v	#REF!	ft/s								
gas flow ra	#REF!	dsc/hr								
emission r	#REF!	lb/hr								
emission r	#REF!	lb/hr								

Reaction over 1 tank 1 hour
 MAX: 205 PPM = 4.9 LBS/HR
 AVE: 82 PPM = 2 LBS/HR
 Page 6

CHPPM WILL
 PROVIDE THIS
 DATA

code of federal regulations

Labor

29

PART 1910 (§1910.1000 TO END)
Revised as of July 1, 1999



§ 1910.1000

29 CFR Ch. XVII (7-1-01 Edition)

TABLE Z-1—LIMITS FOR AIR CONTAMINANTS—Continued

Substance	CAS No. (c)	ppm (a) ¹	mg/m ³ (b) ¹	Skin designation
Selenium compounds (as Se)	7782-49-2		0.2	
Selenium hexafluoride (as Se)	7783-79-1	0.05	0.4	
Silica, amorphous, precipitated and gel	112926-00-8		(³)	
Silica, amorphous, diatomaceous earth, containing less than 1% crystalline silica	61790-53-2		(³)	
Silica, crystalline cristobalite, respirable dust	14464-46-1		(³)	
Silica, crystalline quartz, respirable dust	14808-60-7		(³)	
Silica, crystalline tripoli (as quartz), respirable dust	1317-95-9		(³)	
Silica, crystalline tridymite, respirable dust	15468-32-3		(³)	
Silica, fused, respirable dust	60676-86-0		(³)	
Silicates (less than 1% crystalline silica)				
Mica (respirable dust)	12001-26-2		(³)	
Soapstone, total dust			(³)	
Soapstone, respirable dust			(³)	
Talc (containing asbestos); use asbestos limit; see 29 CFR 1910.1001			(³)	
Talc (containing no asbestos), respirable dust	14807-96-6		(³)	
Tremolite, asbestosiform; see 1910.1001				
Silicon	7440-21-3			
Total dust			15	
Respirable fraction			5	
Silicon carbide	409-21-2			
Total dust			15	
Respirable fraction			5	
Silver, metal and soluble compounds (as Ag)	7440-22-4		0.01	
Soapstone; see Silicates				
Sodium fluoroacetate	62-74-8		0.05	X
Sodium hydroxide	1310-73-2		2	
Starch	9005-25-8			
Total dust			15	
Respirable fraction			5	
Stibine	7803-52-3	0.1	0.5	
Stoddard solvent	8052-41-3	500	2900	
Strychnine	57-24-9		0.15	
Styrene	100-42-5		(²)	
Sucrose	57-50-1			
Total dust			15	
Respirable fraction			5	
Sulfur dioxide	7446-09-5	5	13	
Sulfur hexafluoride	2551-62-4	1000	6000	
Sulfuric acid	7664-93-9		1	
Sulfur monochloride	10025-67-9	1	6	
Sulfur pentafluoride	5714-22-7	0.025	0.25	
Sulfuryl fluoride	2699-79-8	5	20	
Syston; see Dometon				
2,4,5-T (2,4,5-trichlorophenoxyacetic acid)	93-76-5		10	
Talc; see Silicates				
Tantalum, metal and oxide dust	7440-25-7		5	
TEPP (Tetraethyl pyrophosphate)	3689-24-5		0.2	X
Tellurium and compounds (as Te)	13494-80-9		0.1	
Tellurium hexafluoride (as Te)	7783-80-4	0.02	0.2	
Temephos	3383-96-8			
Total dust			15	
Respirable fraction			5	
TEPP (Tetraethyl pyrophosphate)	107-49-3		0.05	X
Terphenyls	26140-80-3	(C)1	(C)9	
1,1,1,2-Tetrachloro-2,2-difluoroethane	76-11-9	500	4170	
1,1,2,2-Tetrachloro-1,2-difluoroethane	76-12-0	500	4170	
1,1,2,2-Tetrachloroethane	79-34-5	5	35	X
Tetrachloroethylene; see Perchloroethylene				
Tetrachloromethane; see Carbon tetrachloride				
Tetrachloronaphthalene	1335-88-2		2	X
Tetraethyl lead (as Pb)	78-00-2		0.075	X
Tetrahydrofuran	109-99-9	200	590	
Tetramethyl lead (as Pb)	75-74-1		0.075	X
Tetramethyl succinonitrile	3333-62-6	0.5	3	X
Tetranitromethane	509-14-8	1	8	
Tetryl (2,4,6-Trinitrophenylmethyl nitramine)	479-45-8		1.5	X
Thallium, soluble compounds (as Tl)	7440-28-0		0.1	X
4,4'-Thiobis (5-tert, Butyl-m-cresol)	96-69-5			
Total dust			15	
Respirable fraction			5	

code of federal regulations

Protection of
Environment

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PARTS 300 TO 399
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(h) The health professional receiving the trade secret information may disclose it to EPA only under the following circumstances: The health professional must believe that such disclosure is necessary in order to learn from the Agency additional information about the chemical necessary to assist him in carrying out the responsibilities set forth in paragraphs (c), (d), and (e) of this section. Such information comprises facts regarding adverse health and environmental effects.

PART 355—EMERGENCY PLANNING AND NOTIFICATION

- Sec.
355.10 Purpose.
355.20 Definitions.
355.30 Emergency planning.
355.40 Emergency release notification.
355.50 Penalties.

APPENDIX A TO PART 355- THE LIST OF EXTREMELY HAZARDOUS SUBSTANCES AND THEIR THRESHOLD PLANNING QUANTITIES (ALPHABETICAL ORDER)

APPENDIX B TO PART 355- THE LIST OF EXTREMELY HAZARDOUS SUBSTANCES AND THEIR THRESHOLD PLANNING QUANTITIES (CAS NUMBER ORDER)

AUTHORITY: 42 U.S.C. 11002, 11004, and 11048.

SOURCE: 52 FR 13395, Apr. 22, 1987, unless otherwise noted.

§ 355.10 Purpose.

This regulation establishes the list of extremely hazardous substances, threshold planning quantities, and facility notification responsibilities necessary for the development and implementation of State and local emergency response plans.

§ 355.20 Definitions.

Act means the Superfund Amendments and Reauthorization Act of 1986.
CERCLA means the Comprehensive Environmental Response, Compensation and Liability Act of 1980, as amended.

CERCLA Hazardous Substance means a substance on the list defined in section 101(14) of CERCLA.

NOTE: Listed CERCLA hazardous substances appear in table 302.4 of 40 CFR part 302.

Chief Executive Officer of the tribe means the person who is recognized by the Bureau of Indian Affairs as the

chief elected administrative officer of the tribe.

Commission means the emergency response commission for the State in which the facility is located except where the facility is located in Indian Country, in which case, *commission* means the emergency response commission for the tribe under whose jurisdiction the facility is located. In absence of an emergency response commission, the Governor and the chief executive officer, respectively, shall be the commission. Where there is a cooperative agreement between a State and a Tribe, the commission shall be the entity identified in the agreement.

Committee or Local emergency planning committee means the local emergency planning committee appointed by the emergency response commission.

Environment includes water, air, and land and the interrelationship which exists among and between water, air, and land and all living things.

Extremely hazardous substance means a substance listed in appendices A and B of this part.

Facility means all buildings, equipment, structure, and other stationary items that are located on a single site or on contiguous or adjacent sites and which are owned or operated by the same person (or by any person which controls, is controlled by, or under common control with, such person). *Facility* shall include manmade structures in which chemicals are purposefully placed or removed through human means such that it functions as a containment structure for human use. For purposes of emergency release notification, the term includes motor vehicles, rolling stock, and aircraft.

Hazardous chemical means any hazardous chemical as defined under § 1910.1200(c) of Title 29 of the Code of Federal Regulations, except that such term does not include the following substances:

(1) Any food, food additive, color additive, drug, or cosmetic regulated by the Food and Drug Administration.

(2) Any substance present as a solid in any manufactured item to the extent exposure to the substance does not occur under normal conditions of use.

(3) Any substance to the extent it is used for personal, family, or household

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purposes, or is present in the same form and concentration as a product packaged for distribution and use by the general public.

(4) Any substance to the extent it is used in a research laboratory or a hospital or other medical facility under the direct supervision of a technically qualified individual.

(5) Any substance to the extent it is used in routine agricultural operations or is a fertilizer held for sale by a retailer to the ultimate customer.

Indian Country means *Indian country* as defined in 18 U.S.C. 1151. That section defines Indian country as:

(a) All land within the limits of any Indian reservation under the jurisdiction of the United States government, notwithstanding the issuance of any patent, and including rights-of-way running through the reservation;

(b) All dependent Indian communities within the borders of the United States whether within the original or subsequently acquired territory thereof, and whether within or without the limits of a State; and

(c) All Indian allotments, the Indian titles to which have not been extinguished, including rights-of-way running through the same.

Indian tribe means those tribes federally recognized by the Secretary of the Interior.

Mixture means a heterogeneous association of substances where the various individual substances retain their identities and can usually be separated by mechanical means. Includes solutions or compounds but does not include alloys or amalgams.

Person means any individual, trust, firm, joint stock company, corporation (including a government corporation), partnership, association, State, municipality, commission, political subdivision of a State, or interstate body.

Release means any spilling, leaking, pumping, pouring, emitting, emptying, discharging, injecting, escaping, leaching, dumping, or disposing into the environment (including the abandonment or discarding of barrels, containers, and other closed receptacles) of any hazardous chemical, extremely hazardous substance, or CERCLA hazardous substance.

Reportable quantity means, for any CERCLA hazardous substance, the reportable quantity established in table 302.4 of 40 CFR part 302, for such substance, for any other substance, the reportable quantity is one pound.

State means any State of the United States, the District of Columbia, the Commonwealth of Puerto Rico, Guam, American Samoa, the United States Virgin Islands, the Northern Mariana Islands, any other territory or possession over which the United States has jurisdiction and Indian Country.

Threshold planning quantity means, for a substance listed in appendices A and B, the quantity listed in the column "threshold planning quantity" for that substance.

[52 FR 13395, Apr. 22, 1987; 54 FR 38853, Sept. 21, 1989, as amended at 55 FR 30645, July 26, 1990]

§ 355.30 Emergency planning.

(a) *Applicability.* The requirements of this section apply to any facility at which there is present an amount of any extremely hazardous substance equal to or in excess of its threshold planning quantity, or designated, after public notice and opportunity for comment, by the Commission or the Governor for the State in which the facility is located. For purposes of this section, an amount of any extremely hazardous substance means the total amount of an extremely hazardous substance present at any one time at a facility at concentrations greater than one percent by weight, regardless of location, number of containers, or method of storage.

(b) *Emergency planning notification.* The owner or operator of a facility subject to this section shall provide notification to the Commission that it is a facility subject to the emergency planning requirements of this part. Such notification shall be provided: on or before May 17, 1987 or within sixty days after a facility first becomes subject to the requirements of this section, whichever is later.

(c) *Facility emergency coordinator.* The owner or operator of a facility subject to this section shall designate a facility representative who will participate in the local emergency planning process as a facility emergency response

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coordinator. The owner or operator shall notify the local emergency planning committee (or the Governor if there is no committee) of the facility representative on or before September 17, 1987 or 30 days after establishment of a local emergency planning committee, whichever is earlier.

(d) *Provision of information.* (1) The owner or operator of a facility subject to this section shall inform the local emergency planning committee of any changes occurring at the facility which may be relevant to emergency planning.

(2) Upon request of the local emergency planning committee, the owner or operator of a facility subject to this section shall promptly provide to the committee any information necessary for development or implementation of the local emergency plan.

(e) *Calculation of TPQs for solids and mixtures.* (1) If a container or storage vessel holds a mixture or solution of an extremely hazardous substance, then the concentration of extremely hazardous substance, in weight percent (greater than 1 percent sign), shall be multiplied by the mass (in pounds) in the vessel to determine the actual quantity of extremely hazardous substance therein.

(2)(i) Extremely hazardous substances that are solids are subject to either of two threshold planning quantities as shown on appendices A and B (i.e., 500/10,000 pounds). The lower quantity applies only if the solid exists in powdered form and has a particle size less than 100 microns; or is handled in solution or in molten form; or meets the criteria for a National Fire Protection Association (NFPA) rating of 2, 3 or 4 for reactivity. If the solid does not meet any of these criteria, it is subject to the upper (10,000 pound) threshold planning quantity as shown in appendices A and B.

(ii) The 100 micron level may be determined by multiplying the weight percent of solid with a particle size less than 100 microns in a particular container by the quantity of solid in the container.

(iii) The amount of solid in solution may be determined by multiplying the weight percent of solid in the solution

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in a particular container by the quantity of solution in the container.

(iv) The amount of solid in molten form must be multiplied by 0.3 to determine whether the lower threshold planning quantity is met.

§ 355.40 Emergency release notification.

(a) *Applicability.* (1) The requirements of this section apply to any facility: (i) at which a hazardous chemical is produced, used or stored and (ii) at which there is release of a reportable quantity of any extremely hazardous substance or CERCLA hazardous substance.

(2) This section does not apply to:

(i) Any release which results in exposure to persons solely within the boundaries of the facility;

(ii) Any release which is a *federally permitted release* as defined in section 101 (10) of CERCLA;

(iii) Any release that is continuous and stable in quantity and rate under the definitions in 40 CFR 302.8(b). Exemption from notification under this subsection does not include exemption from:

(A) Initial notifications as defined in 40 CFR 302.8 (d) and (e);

(B) Notification of a "statistically significant increase," defined in 40 CFR 302.8(b) as any increase above the upper bound of the reported normal range, which is to be submitted to the community emergency coordinator for the local emergency planning committee for any area likely to be affected by the release and to the State emergency response commission of any State likely to be affected by the release;

(C) Notification of a "new release" as defined in 40 CFR 302.8(g)(1); or

(D) Notification of a change in the normal range of the release as required under 40 CFR 302.8(g)(2).

(iv) Any release of a pesticide product exempt from CERCLA section 103(a) reporting under section 103(e) of CERCLA;

(v) Any release not meeting the definition of release under Section 101(22) of CERCLA, and therefore exempt from Section 103(a) reporting; and

(vi) Any radionuclide release which occurs:

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(A) Naturally in soil from land holdings such as parks, golf courses, or other large tracts of land.

(B) Naturally from land disturbance activities, including farming, construction, and land disturbance incidental to extraction during mining activities, except that which occurs at uranium, phosphate, tin, zircon, hafnium, vanadium, monazite, and rare earth mines. Land disturbance incidental to extraction includes: land clearing; overburden removal and stockpiling; excavating, handling, transporting, and storing ores and other raw (not beneficiated or processed) materials; and replacing in mined-out areas coal ash, earthen materials from farming or construction, or overburden or other raw materials generated from the exempted mining activities.

(C) From the dumping and transportation of coal and coal ash (including fly ash, bottom ash, and boiler slags), including the dumping and land spreading operations that occur during coal ash uses.

(D) From piles of coal and coal ash, including fly ash, bottom ash, and boiler slags.

NOTE TO PARAGRAPH (a): Releases of CERCLA hazardous substances are subject to the release reporting requirements of CERCLA section 103, codified at 40 CFR part 302, in addition to the requirements of this part.

(b) *Notice requirements.* (1) The owner or operator of a facility subject to this section shall immediately notify the community emergency coordinator for the local emergency planning committee of any area likely to be affected by the release and the State emergency response commission of any State likely to be affected by the release. If there is no local emergency planning committee, notification shall be provided under this section to relevant local emergency response personnel.

(2) The notice required under this section shall include the following to the extent known at the time of notice and so long as no delay in notice or emergency response results:

(i) The chemical name or identity of any substance involved in the release.

(ii) An indication of whether the substance is an extremely hazardous substance.

(iii) An estimate of the quantity of any such substance that was released into the environment.

(iv) The time and duration of the release.

(v) The medium or media into which the release occurred.

(vi) Any known or anticipated acute or chronic health risks associated with the emergency and, where appropriate, advice regarding medical attention necessary for exposed individuals.

(vii) Proper precautions to take as a result of the release, including evacuation (unless such information is readily available to the community emergency coordination pursuant to the emergency plan).

(viii) The names and telephone number of the person or persons to be contacted for further information.

(3) As soon as practicable after a release which requires notice under (b)(1) of this section, such owner or operator shall provide a written follow-up emergency notice (or notices, as more information becomes available) setting forth and updating the information required under paragraph (b)(2) of this section, and including additional information with respect to:

(i) Actions taken to respond to and contain the release,

(ii) Any known or anticipated acute or chronic health risks associated with the release, and,

(iii) Where appropriate, advice regarding medical attention necessary for exposed individuals.

(4) *Exceptions.* (i) Until April 30, 1988, in lieu of the notice specified in paragraph (b)(2) of this section, any owner or operator of a facility subject to this section from which there is a release of a CERCLA hazardous substance which is not an extremely hazardous substance and has a statutory reportable quantity may provide the same notice required under CERCLA section 103(a) to the local emergency planning committee.

(ii) An owner or operator of a facility from which there is a transportation-related release may meet the requirements of this section by providing the information indicated in paragraph (b)(2) to the 911 operator, or in the absence of a 911 emergency telephone number, to the operator. For purposes

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of this paragraph, a *transportation-related release* means a release during transportation, or storage incident to transportation if the stored substance is moving under active shipping papers and has not reached the ultimate consignee.

[52 FR 13395, Apr. 22, 1987, as amended at 54 FR 22543, May 24, 1989; 55 FR 30188, July 24, 1990; 63 FR 13475, Mar. 19, 1998; 64 FR 13115, Mar. 17, 1999]

§ 355.50 Penalties.

(a) *Civil penalties.* Any person who fails to comply with the requirements of § 355.40 shall be subject to civil penalties of up to \$25,000 for each violation in accordance with section 325(b)(1) of the Act.

(b) *Civil penalties for continuing violations.* Any person who fails to comply

with the requirements of § 355.40 shall be subject to civil penalties of up to \$25,000 for each day during which the violation continues, in accordance with section 325(b)(2) of the Act. In the case of a second or subsequent violation, any such person may be subject to civil penalties of up to \$75,000 for each day the violation continues, in accordance with section 325(b)(2) of the Act.

(c) *Criminal penalties.* Any person who knowingly and willfully fails to provide notice in accordance with § 355.40 shall, upon conviction, be fined not more than \$25,000 or imprisoned for not more than two (2) years, or both (or, in the case of a second or subsequent conviction, shall be fined not more than \$50,000 or imprisoned for not more than five (5) years, or both) in accordance with section 325(b)(4) of the Act.

APPENDIX A TO PART 355- THE LIST OF EXTREMELY HAZARDOUS SUBSTANCES
AND THEIR THRESHOLD PLANNING QUANTITIES

[Alphabetical Order]

CAS No.	Chemical name	Notes	Reportable quantity* (pounds)	Threshold planning quantity (pounds)
75-66-5	Acetone Cyanohydrin		10	1,000
1752-30-3	Acetone Thiocarbamide		1,000	1,000/10,000
107-02-8	Acrolein		1	500
79-06-1	Acrylamide	i	5,000	1,000/10,000
107-13-1	Acrylonitrile	i	100	10,000
814-68-6	Acrylyl Chloride	h	100	100
111-69-3	Adiponitrile	i	1,000	1,000
116-06-3	Aldicarb	c	1	100/10,000
309-00-2	Aldrin		1	500/10,000
107-18-6	Allyl Alcohol		100	1,000
107-11-9	Allylamine		500	500
20859-73-8	Aluminum Phosphide	b	100	500
54-62-6	Aminopterin		500	500/10,000
78-53-5	Ammonia		500	500
3734-97-2	Ammonia Oxalate		100	100/10,000
7664-41-7	Ammonia	i	100	500
300-62-9	Amphetamine		1,000	1,000
62-53-3	Aniline	i	5,000	1,000
88-05-1	Aniline, 2,4,6-Trimethyl-		500	500
7783-70-2	Antimony Pentafluoride		500	500
1397-94-0	Antimony A	c	1,000	1,000/10,000
86-88-4	ANTU		100	500/10,000
1303-28-2	Arsenic Pentoxide		1	100/10,000
1327-53-3	Arsenous Oxide	h	1	100/10,000
7784-34-1	Arsenous Trichloride		1	500
7784-42-1	Arsine		100	100
2642-71-9	Azinphos-Ethyl		100	100/10,000
86-50-0	Azinphos-Methyl		1	10/10,000
98-87-3	Benzal Chloride		5,000	500
98-16-8	Benzenamine, 3-(Trifluoromethyl)-		500	500
100-14-1	Benzene, 1-(Chloromethyl)-4-Nitro		500	500/10,000
98-05-5	Benzenesulfonic Acid		10	10/10,000
3615-21-2	Benzimidazole, 4,5-Dichloro-2-(Trifluoromethyl)-	g	500	500/10,000
98-07-7	Benzonitrile		10	100
100-44-7	Benzyl Chloride		100	500
140-29-4	Benzyl Cyanide	h	500	500
15271-41-7	Bicyclo[2.2.1]heptane-2-Carbonitrile, 5-Chloro-6-(((Methylamino)Carbonyl)Oxy)Imino-, (1s-(1-alpha,2-beta,4-alpha,5-alpha,6E))-		500	500/10,000
534-07-6	Bis(Chloromethyl) Ketone		10	10/10,000

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[Alphabetical Order]

CAS No.	Chemical name	Notes	Reportable quantity * (pounds)	Threshold planning quantity (pounds)
947-02-4	Phosfolan		100	100/10,000
75-44-6	Phosgene	i	10	10
732-11-6	Phosmet		10	10/10,000
13171-21-6	Phosphamidon		100	100
7803-51-2	Phosphine		100	500
2703-13-1	Phosphonothioic Acid, Methyl-, O-Ethyl O-(4-(Methylthio) Phenyl) Ester		500	500
50782-69-9	Phosphonothioic Acid, Methyl-, S-(2-(Bis(1Methylethyl)Amino)Ethyl) O-Ethyl Ester		100	100
2585-30-7	Phosphonothioic Acid, Methyl-, O-(4-Nitrophenyl) O-Phenyl Ester		500	500
3254-63-5	Phosphoric Acid, Dimethyl 4-(Methylthio)Phenyl Ester		500	500
2587-90-8	Phosphorothioic Acid, O,O-Dimethyl-S-(2-Methylthio) Ethyl Ester	c, g	500	500
7723-14-0	Phosphorus	b, h	1	100
10025-87-3	Phosphorus Oxichloride		1,000	500
10026-13-6	Phosphorus Pentachloride	b	500	500
7719-12-2	Phosphorus Trichloride		1,000	1,000
57-47-6	Physostigmine	d	1	100/10,000
57-64-7	Physostigmine, Salicylate (1:1)	d	1	100/10,000
124-87-8	Picrotoxin		500	500/10,000
110-69-4	Piperidine		1,000	1,000
23505-41-1	Pirimifos-Ethyl		1,000	1,000
10124-50-2	Potassium Arsenite		1	500/10,000
151-50-8	Potassium Cyanide	b	10	100
506-61-6	Potassium Silver Cyanide	b	1	500
2631-37-0	Promecarb	d, h	1	500/10,000
106-96-7	Propargyl Bromide		10	10
57-57-8	Propiolactone, Beta-		10	500
107-12-0	Propionitrile		10	500
542-76-7	Propionitrile, 3-Chloro		1,000	1,000
70-69-9	Propiophenone, 4-Amino	g	100	100/10,000
109-61-5	Propyl Chloroformate		500	500
75-56-8	Propylene Oxide	i	100	10,000
75-55-8	Propyleneimine		1	10,000
2275-18-5	Prothoate		100	100/10,000
129-00-0	Pyrene	c	5,000	1,000/10,000
140-76-1	Pyridine, 2-Methyl-5-Vinyl		500	500
504-24-5	Pyridine, 4-Amino	h	1,000	500/10,000
1124-33-0	Pyridine, 4-Nitro-J-Oxide		500	500/10,000
53558-25-1	Pyriminil	h	100	100/10,000
14167-18-1	Salcomine		500	500/10,000
107-44-8	Sarin	h	10	10
7783-00-8	Selenious Acid		10	1,000/10,000
7791-23-3	Selenium Oxichloride		500	500
583-41-7	Semicarbazide Hydrochloride		1,000	1,000/10,000
3037-72-7	Silane, (4-Aminobutyl)Diethoxymethyl-		1,000	1,000
7631-69-2	Sodium Arsenate		1	1,000/10,000
7784-45-5	Sodium Arsenite		1	500/10,000
26628-22-8	Sodium Azide (Na(N ₃))	b	1,000	500
124-65-2	Sodium Cacodylate		100	100/10,000
143-33-9	Sodium Cyanide (Na(CN))	b	10	100
62-74-8	Sodium Fluoroacetate		10	10/10,000
13410-01-0	Sodium Selenate		100	100/10,000
10102-18-8	Sodium Selenite	h	100	100/10,000
10102-20-2	Sodium Tellurite		500	500/10,000
900-95-8	Stannane, Acetoxytriphenyl	g	500	500/10,000
57-24-9	Strychnine	c	10	100/10,000
60-41-3	Strychnine Sulfate		10	100/10,000
3689-24-5	Sulfotep		100	500
3569-57-1	Sulfoxide, 3-Chloropropyl Octyl		500	500
7446-09-5	Sulfur Dioxide	i	500	500
7783-60-0	Sulfur Tetrafluoride		100	100
7446-11-9	Sulfur Trioxide	b	100	100
7684-93-9	Sulfuric Acid		1,000	1,000
77-81-6	Tellur	c, h	10	10
7783-80-4	Tellurium Hexafluoride	k	100	100
107-49-3	TEPP		10	100
13071-79-9	Terbulos	h	100	100
78-00-2	Tetraethyllead	c	10	100
597-64-8	Tetraethyltin	c	100	100
75-74-1	Tetramethyllead	c, i	100	100
509-14-8	Tetranitromethane		10	500

CONFIRMED BY EPCRA NOTLINE
 450
 SULFUR DIOXIDE RQ = ONE POUND
 DANA 28 FEB 96

Appendix B: Air Scrubber Design Corresponding to E17-36FS-002

Form MSE-135

(Rev. 10-95)

Prepared S. Kujawa 9/10/01

Checked

File

Project WVA IWTP

Subject Absorber Design

MSE

MSE Technology Applications, Inc.

P.O. Box 4078

Butte, MT 59702

(406) 494-7100 FAX (406) 494-7230

Summary

Attached is the absorber design corresponding to E17-36FS-002.

The 002 design assumes that all vents are drawn to the absorber by means of an induced draft fan. Only the reactor vents contain SO₂, and all other vents contain H₂S.

ChemCad calculations show that SO₂ is absorbed about 100 percent when caustic is used; only about 89 percent when water, only, is used. H₂S is absorbed at about 50 percent in both cases.

The absorber is about 4.5 feet in diameter and approximately 20 feet tall. About 12 feet of packing preredquired. Once vendors are contracted, I expect a shorter absorber will be recommended.

ChemCAD 5.1.0

Page 1

Job Name: wvaIWTF1-3 Date: 08/28/2001 Time: 09:06:24

FLOWSHEET SUMMARY

Equipment	Label	Stream Numbers
1	MIXE	1 9 -10
2	MIXE	3 4 -2
3	PUMP	6 -7
4	DIVI	7 -3 -8
5	SCDS	2 10 -5 -6

Stream Connections

Stream	Equipment From To	Stream	Equipment From To	Stream	Equipment From To
1		5	5	9	1
2	2 5	6	5 3	10	1 5
3	4 2	7	3 4		
4	2	8	4		

Calculation mode : Sequential
Flash algorithm : Electrolyte

Equipment Calculation Sequence
1 5 3 4 2

Equipment Recycle Sequence
5 3 4 2

Recycle Cut Streams
2

Recycle Convergence Method: Wegstein

Wegstein lower bound -5.00 Wegstein upper bound 0.00
Acceleration frequency 4
Max. loop iterations 100
Flash Damping factor 0.30

Recycle Convergence Tolerance

Flow rate 5.000E-005
Temperature 1.000E-003
Pressure 1.000E-003
Enthalpy 1.000E-003
Vapor frac. 1.000E-003

Recycle calculation has converged.

COMPONENTS

ChemCAD 5.1.0

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Job Name: wvaIWTP1-3 Date: 08/28/2001 Time: 09:06:24

ID #	Name
1	46 Nitrogen
2	47 Oxygen
3	62 Water
4	51 Sulfur Dioxide
5	50 Hydrogen Sulfide
6	992 Sulphur
7	1 Hydrogen
8	431 Sulfuric Acid

THERMODYNAMICS

K-value model : NRTL
 No correction for vapor fugacity
 Enthalpy model : Latent Heat
 Liquid density : Library

NRTL Parameters:

I	J	BiJ	Bji	Alpha	Aij	Aji
3	4	-372.398	2383.660	0.104	0.000	0.000
3	8	-1228.660	-1894.250	0.243	0.000	0.000

Warning : BIP matrix is less than 50 % full.

ELECTROLYTE DATA INPUT

Electrolyte model: NRTL

ID #	Species
1	1005 H2O
2	1002 H+
3	1004 OH-
4	1029 H2S
5	1028 HS-
6	1024 S--
7	1025 SO2
8	1026 SO3--
9	1030 HSO3-
10	1033 H2SO4
11	1031 HSO4-
12	1027 SO4--

No. of reactions 7

Reaction Stoichiometrics and Parameters:

Reaction $\ln K = A + B / T + C \ln T + D * T + E * T * T$; T, deg K

Reaction 1 Base = Molal

A	B	C	D	E
1.4093e+002	-1.3446e+004	-2.2477e+001	0.0000e+000	0.0000e+000

Species	Stoichiometrics	Form
1	-1	H2O

ChemCAD 5.1.0

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Job Name: wvaIWTP1-3 Date: 08/28/2001 Time: 09:06:24

2	1	H+
3	1	OH-

Reaction 2 Base = Molal

A	B	C	D	E
-7.4890e+000	-7.2112e+003	0.0000e+000	0.0000e+000	0.0000e+000

Species	Stoichiometrics	Form
5	-1	HS-
2	1	H+
6	1	S--

Reaction 3 Base = Molal

A	B	C	D	E
2.1860e+002	-1.2995e+004	-3.3547e+001	0.0000e+000	0.0000e+000

Species	Stoichiometrics	Form
4	-1	H2S
2	1	H+
5	1	HS-

Reaction 4 Base = Molal

A	B	C	D	E
-1.9621e+000	6.3740e+002	0.0000e+000	-1.5134e-002	0.0000e+000

Species	Stoichiometrics	Form
7	-1	SO2
1	-1	H2O
2	1	H+
9	1	HSO3-

Reaction 5 Base = Molal

A	B	C	D	E
-2.1274e+001	1.3334e+003	0.0000e+000	0.0000e+000	0.0000e+000

Species	Stoichiometrics	Form
9	-1	HSO3-
2	1	H+
8	1	SO3--

Reaction 6 Base = Molal

A	B	C	D	E
0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000

Species	Stoichiometrics	Form
10	-1	H2SO4
11	1	HSO4-
2	1	H+

Reaction 7 Base = Molal

A	B	C	D	E
9.5465e+000	-7.3337e+002	0.0000e+000	-3.8845e-002	0.0000e+000

Species	Stoichiometrics	Form
11	-1	HSO4-
2	1	H+

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Job Name: wvaIWTP1-3 Date: 08/28/2001 Time: 09:06:24

12 1 SO4--

Henry's Constants: $\ln H = A + B / T + C \ln T + D * T$
 $H = \text{kg-atm/mole}; T, \text{deg K}$

	A	B	C	D
2 Oxygen	1.0459e+001	-1.0854e+003	0.0000e+000	0.0000e+000
4 Sulfur Dioxide	6.8418e+001	-5.5788e+003	-8.7615e+000	0.0000e+000
5 Hydrogen Sulfide	3.4260e+002	-1.3237e+004	-5.5055e+001	5.9565e-002
8 Sulfuric Acid	-4.8528e+000	-6.3972e+003	1.9016e+000	0.0000e+000

Electrolyte NRTL parameters

IDi	IDj	TijA	TijB	TjiA	TjiB	Alpha
1005	1025	-29.976	-3371	-2.055	2459.7	0.13977
1005	1029	-3.674	1155.9	-3.674	1155.9	0.2
1005	1033	-7.12029	696.966	3.56505	1357.61	0.113532

IDm	IDc	IDa	TmcaA	TmcaB	TmcaC	TcamA	TcamB	TcamC	Alpha
1005	1002	1030	19.685	1987.7	0	-19.389	1404.3	0	0.22164
1005	1002	1031	-13.4684	-1124.41	40.0089	7.69427	-3008.13	-30.468	0.076502
1005	1002	1027	0.815756	-1749.8	0	-4.45807	280.289	0	0.148914
1033	1002	1031	5.9709	0	0	-9.7482	0	0	0.2

Electrolyte enthalpy model.

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Job Name: wvaIWTF1-3 Date: 08/28/2001 Time: 09:06:24

Overall Mass Balance	lbmol/min		lb/min	
	Input	Output	Input	Output
Nitrogen	11.395	11.395	319.223	319.223
Oxygen	3.029	3.029	96.914	96.914
Water	2.066	2.066	37.213	37.214
Sulfur Dioxide	0.001	0.001	0.046	0.046
Hydrogen Sulfide	0.000	0.000	0.004	0.004
Sulphur	0.000	0.000	0.000	0.000
Hydrogen	0.000	0.000	0.000	0.000
Sulfuric Acid	0.000	0.000	0.000	0.000
Total	16.490	16.490	453.400	453.400

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Job Name: wvaIWTF1-3 Date: 08/28/2001 Time: 09:06:25
EQUIPMENT SUMMARIES

Mixer Summary

Equip. No.	1	2
Name		
Output Pressure psia		14.5000

Pump Summary

Equip. No.	3
Name	
Pressure increase psi	20.0000
Efficiency	0.7500
Calculated power hp	0.9189
Calculated Pout psia	34.5000
Head ft	46.1728
Vol. flow rate gpm	59.0415

Divider Summary

Equip. No.	4
Name	
Split based on	4
Output stream #1	55.0000
Flow rate units	9

Seds Rigorous Distillation Summary

Equip. No.	5
Name	
No. of stages	6
1st feed stage	1
2nd feed stage	6
Est. dist. rate (lbmol/min)	14.4000
Est. stage 1 T F	55.0000
Est. bottom T F	55.0000
Top pressure psia	14.5000
Reflux mole lbmol/min	27.4177
Reflux mass lb/min	493.9602

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Job Name: wvaIWTF1-3 Date: 08/28/2001 Time: 09:06:26
 STREAM PROPERTIES

Stream No.	1	2	3	4
Name	RCTR VENT	TWR LQR	SCRBR RCYCL	MAKE-UP WTR
- - Overall - -				
Molar flow lbmol/min	3.2121	27.4179	25.4751	1.9428
Mass flow lb/min	92.4000	493.9632	458.9632	35.0000
Temp F	68.0000	55.2661	54.1434	70.0000
Pres psia	14.6000	14.5000	34.5000	14.9000
Vapor mole fraction	1.000	0.0000	0.0000	0.0000
Enth MMBtu/min	-0.0031325	-3.3800	-3.1410	-0.23899
Tc F	-217.2387	705.5257	705.5230	705.5600
Pc psia	518.3634	3207.6536	3207.6270	3207.9768
Std. sp gr. air = 1	0.993	0.622	0.622	0.622
Degree API	31.7833	9.8923	9.8921	9.8949
Average mol wt	28.7662	18.0161	18.0162	18.0150
Actual dens lb/ft3	0.0742	62.3688	62.3739	62.2789
Actual vol ft3/min	1245.3430	7.9200	7.3583	0.5620
Std vap 60F scfm	1218.9243	10404.5156	9667.2542	737.2607
- - Vapor only - -				
Molar flow lbmol/min	3.2121			
Mass flow lb/min	92.4000			
Average mol wt	28.7662			
Actual dens lb/ft3	0.0742			
Actual vol ft3/min	1245.3430			
Std liq gpm	12.7895			
Std vap 60F scfm	1218.9243			
Cp Btu/lb-F	0.2432			
Z factor	0.9997			
Visc lbm/ft-hr	0.04351			
Th cond Btu/hr-ft-F	0.0145			
- - Liquid only - -				
Molar flow lbmol/min		27.4179	25.4751	1.9428
Mass flow lb/min		493.9632	458.9632	35.0000
Average mol wt		18.0161	18.0162	18.0150
Actual dens lb/ft3		62.3688	62.3739	62.2789
Actual vol gpm		59.2527	55.0499	4.2044
Std vap 60F scfm		10404.5156	9667.2542	737.2607
Cp Btu/lb-F		1.0025	1.0034	1.0000
Z factor		0.0010	0.0024	0.0010
Visc lbm/ft-hr		2.960	3.007	2.436
Th cond Btu/hr-ft-F		0.3399	0.3393	0.3470
Surf tens dyne/cm		74.1641	74.2697	72.7749

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Job Name: wvaIWTP1-3 Date: 08/28/2001 Time: 09:06:28
 STREAM PROPERTIES

Stream No.	5	6	7	8
Name	STACK	Bottoms	Pmp Dsch	Blowdown
- - Overall - -				
Molar flow lbmol/min	14.6430	27.3225	27.3225	1.8474
Mass flow lb/min	420.1180	492.2455	492.2455	33.2823
Temp F	55.1315	54.0649	54.1434	54.1434
Pres psia	14.5000	14.5000	34.5000	34.5000
Vapor mole fraction	1.000	0.0000	0.0000	0.0000
Enth MMBtu/min	-0.025024	-3.3688	-3.3688	-0.22777
Tc F	-212.9127	705.5230	705.5230	705.5230
Pc psia	513.5980	3207.6248	3207.6248	3207.6248
Std. sp gr. air = 1	0.991	0.622	0.622	0.622
Degree API	31.7157	9.8922	9.8922	9.8921
Average mol wt	28.6908	18.0162	18.0162	18.0162
Actual dens lb/ft3	0.0753	62.3742	62.3739	62.3739
Actual vol ft3/min	5576.1880	7.8918	7.8919	0.5336
Std vap 60F scfm	5556.6870	10368.2865	10368.2865	701.0329
- - Vapor only - -				
Molar flow lbmol/min	14.6430			
Mass flow lb/min	420.1180			
Average mol wt	28.6908			
Actual dens lb/ft3	0.0753			
Actual vol ft3/min	5576.1880			
Std liq gpm	58.1262			
Std vap 60F scfm	5556.6870			
Cp Btu/lb-F	0.2440			
Z factor	0.9996			
Visc lbm/ft-hr	0.04252			
Th cond Btu/hr-ft-F	0.0142			
- - Liquid only - -				
Molar flow lbmol/min		27.3225	27.3225	1.8474
Mass flow lb/min		492.2455	492.2455	33.2823
Average mol wt		18.0162	18.0162	18.0162
Actual dens lb/ft3		62.3742	62.3739	62.3739
Actual vol gpm		59.0416	59.0419	3.9920
Std vap 60F scfm		10368.2865	10368.2865	701.0329
Cp Btu/lb-F		1.0033	1.0033	1.0035
Z factor		0.0010	0.0024	0.0024
Visc lbm/ft-hr		3.009	3.007	3.007
Th cond Btu/hr-ft-F		0.3393	0.3393	0.3393
Surf tens dyne/cm		74.2772	74.2697	74.2697

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Job Name: wvaIWTP1-3 Date: 08/28/2001 Time: 09:06:29
 STREAM PROPERTIES

Stream No.	9	10
Name	BL/CLAR VNT	
- - Overall - -		
Molar flow lbmol/min	11.3354	14.5475
Mass flow lb/min	326.0000	418.4000
Temp F	68.0000	68.0000
Pres psia	14.6000	14.6000
Vapor mole fraction	1.000	1.000
Enth MMBtu/min	-0.010643	-0.013775
Tc F	-217.4531	-217.4058
Pc psia	517.5793	517.7523
Std. sp gr. air = 1	0.993	0.993
Degree API	31.8111	31.8050
Average mol wt	28.7596	28.7610
Actual dens lb/ft3	0.0742	0.0742
Actual vol ft3/min	4394.7630	5640.1062
Std vap 60F scfm	4301.5253	5520.4495
- - Vapor only - -		
Molar flow lbmol/min	11.3354	14.5475
Mass flow lb/min	326.0000	418.4000
Average mol wt	28.7596	28.7610
Actual dens lb/ft3	0.0742	0.0742
Actual vol ft3/min	4394.7630	5640.1062
Std liq gpm	45.1307	57.9202
Std vap 60F scfm	4301.5253	5520.4495
Cp Btu/lb-F	0.2432	0.2432
Z factor	0.9997	0.9997
Visc lbm/ft-hr	0.04351	0.04351
Th cond Btu/hr-ft-F	0.0145	0.0145

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Job Name: wvaIWTP1-3 Date: 08/28/2001 Time: 09:06:29

FLOW SUMMARIES

Stream No.	1	2	3	4
Stream Name	RCTR VENT	TWR LQR	SCRBR RCYCL	MAKE-UP WTR
Temp F	68.0000	55.2661	54.1434	70.0000
Pres psia	14.6000	14.5000	34.5000	14.9000
Enth MMBtu/min	-0.0031325	-3.3800	-3.1410	-0.23899
Vapor mole fraction	1.0000	0.00000	0.00000	0.00000
Total lbmol/min	3.2121	27.4179	25.4751	1.9428
Flowrates in lbmol/min				
Nitrogen	2.5158	0.0003	0.0003	0.0000
Oxygen	0.6683	0.0002	0.0002	0.0000
Water	0.0273	27.4169	25.4741	1.9428
Sulfur Dioxide	0.0007	0.0005	0.0005	0.0000
Hydrogen Sulfide	0.0000	0.0000	0.0000	0.0000
Sulphur	0.0000	0.0000	0.0000	0.0000
Hydrogen	0.0000	0.0000	0.0000	0.0000
Sulfuric Acid	0.0000	0.0000	0.0000	0.0000

Stream No.	5	6	7	8
Stream Name	STACK	Bottoms	Pmp Dsch	Blowdown
Temp F	55.1315	54.0649	54.1434	54.1434
Pres psia	14.5000	14.5000	34.5000	34.5000
Enth MMBtu/min	-0.025024	-3.3688	-3.3688	-0.22777
Vapor mole fraction	1.0000	0.00000	0.00000	0.00000
Total lbmol/min	14.6429	27.3225	27.3225	1.8474
Flowrates in lbmol/min				
Nitrogen	11.3951	0.0003	0.0003	0.0000
Oxygen	3.0286	0.0002	0.0002	0.0000
Water	0.2184	27.3214	27.3214	1.8473
Sulfur Dioxide	0.0007	0.0006	0.0006	0.0000
Hydrogen Sulfide	0.0001	0.0000	0.0000	0.0000
Sulphur	0.0000	0.0000	0.0000	0.0000
Hydrogen	0.0000	0.0000	0.0000	0.0000
Sulfuric Acid	0.0000	0.0000	0.0000	0.0000

Stream No.	9	10
Stream Name	BL/CLAR VNT	
Temp F	68.0000	68.0000
Pres psia	14.6000	14.6000
Enth MMBtu/min	-0.010643	-0.013775
Vapor mole fraction	1.0000	1.0000
Total lbmol/min	11.3354	14.5475
Flowrates in lbmol/min		
Nitrogen	8.8794	11.3951
Oxygen	2.3603	3.0286
Water	0.0955	0.1228
Sulfur Dioxide	0.0000	0.0007
Hydrogen Sulfide	0.0001	0.0001
Sulphur	0.0000	0.0000
Hydrogen	0.0000	0.0000
Sulfuric Acid	0.0000	0.0000

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Job Name: wvaIWTP1-3 Date: 08/28/2001 Time: 09:06:29

Electrolyte Compositions

Stream No.	1	2	3	4
Stream Name	RCTR VENT	TWR LQR	SCRBR RCYCL	MAKE-UP WTR
Temp F	68.0000	55.2661	54.1434	70.0000
Pres psia	14.6000	14.5000	34.5000	14.9000
Ph value	0.0000	3.0113	2.9825	7.0643
Ionic strength molal	0.0000	0.0010	0.0010	0.0000
Flowrates in lbmol/min				
H2O	0.0000	27.4165	25.4736	1.9428
H+	0.0000	0.0005	0.0005	0.0000
OH-	0.0000	0.0000	0.0000	0.0000
H2S	0.0000	0.0000	0.0000	0.0000
HS-	0.0000	0.0000	0.0000	0.0000
S--	0.0000	0.0000	0.0000	0.0000
SO2	0.0000	0.0000	0.0000	0.0000
SO3--	0.0000	0.0000	0.0000	0.0000
HSO3-	0.0000	0.0005	0.0005	0.0000
H2SO4	0.0000	0.0000	0.0000	0.0000
HSO4-	0.0000	0.0000	0.0000	0.0000
SO4--	0.0000	0.0000	0.0000	0.0000

Stream No.	5	6	7	8
Stream Name	STACK	Bottoms	Pmp Dsch	Blowdown
Temp F	55.1315	54.0649	54.1434	54.1434
Pres psia	14.5000	14.5000	34.5000	34.5000
Ph value	0.0000	2.9823	2.9825	2.9825
Ionic strength molal	0.0000	0.0010	0.0010	0.0010
Flowrates in lbmol/min				
H2O	0.0000	27.3209	27.3209	1.8473
H+	0.0000	0.0005	0.0005	0.0000
OH-	0.0000	0.0000	0.0000	0.0000
H2S	0.0000	0.0000	0.0000	0.0000
HS-	0.0000	0.0000	0.0000	0.0000
S--	0.0000	0.0000	0.0000	0.0000
SO2	0.0000	0.0001	0.0001	0.0000
SO3--	0.0000	0.0000	0.0000	0.0000
HSO3-	0.0000	0.0005	0.0005	0.0000
H2SO4	0.0000	0.0000	0.0000	0.0000
HSO4-	0.0000	0.0000	0.0000	0.0000
SO4--	0.0000	0.0000	0.0000	0.0000

Stream No.	9	10
Stream Name	BL/CLAR VNT	
Temp F	68.0000	68.0000
Pres psia	14.6000	14.6000
Ph value	0.0000	0.0000
Ionic strength molal	0.0000	0.0000
Flowrates in lbmol/min		
H2O	0.0000	0.0000
H+	0.0000	0.0000
OH-	0.0000	0.0000
H2S	0.0000	0.0000
HS-	0.0000	0.0000
S--	0.0000	0.0000
SO2	0.0000	0.0000

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Job Name: wvaIWTP1-3 Date: 08/28/2001 Time: 09:06:29
Electrolyte Compositions

SO3--	0.0000	0.0000
HSO3-	0.0000	0.0000
H2SO4	0.0000	0.0000
HSO4-	0.0000	0.0000
SO4--	0.0000	0.0000

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Job Name: wvaIWTP1-3 Date: 08/28/2001 Time: 09:06:29

FLOW SUMMARIES

Stream No.	1	2	3	4
Stream Name	RCTR VENT	TWR LQR	SCRBR RCYCL	MAKE-UP WTR
Temp F	68.0000	55.2661	54.1434	70.0000
Pres psia	14.6000	14.5000	34.5000	14.9000
Enth MMBtu/min	-0.0031325	-3.3800	-3.1410	-0.23899
Vapor mass fraction	1.0000	0.00000	0.00000	0.00000
Total lb/min	92.4000	493.9632	458.9632	35.0000
Flowrates in lb/min				
Nitrogen	70.4767	0.0082	0.0082	0.0000
Oxygen	21.3850	0.0050	0.0050	0.0000
Water	0.4920	493.9162	458.9162	35.0000
Sulfur Dioxide	0.0463	0.0337	0.0337	0.0000
Hydrogen Sulfide	0.0000	0.0000	0.0000	0.0000
Sulphur	0.0000	0.0000	0.0000	0.0000
Hydrogen	0.0000	0.0000	0.0000	0.0000
Sulfuric Acid	0.0000	0.0000	0.0000	0.0000

Stream No.	5	6	7	8
Stream Name	STACK	Bottoms	Pmp Dsch	Blowdown
Temp F	55.1315	54.0649	54.1434	54.1434
Pres psia	14.5000	14.5000	34.5000	34.5000
Enth MMBtu/min	-0.025024	-3.3688	-3.3688	-0.22777
Vapor mass fraction	1.0000	0.00000	0.00000	0.00000
Total lb/min	420.1180	492.2455	492.2455	33.2823
Flowrates in lb/min				
Nitrogen	319.2227	0.0088	0.0088	0.0006
Oxygen	96.9131	0.0054	0.0054	0.0004
Water	3.9348	492.1951	492.1951	33.2789
Sulfur Dioxide	0.0435	0.0362	0.0362	0.0024
Hydrogen Sulfide	0.0038	0.0000	0.0000	0.0000
Sulphur	0.0000	0.0000	0.0000	0.0000
Hydrogen	0.0000	0.0000	0.0000	0.0000
Sulfuric Acid	0.0000	0.0000	0.0000	0.0000

Stream No.	9	10
Stream Name	BL/CLAR VNT	
Temp F	68.0000	68.0000
Pres psia	14.6000	14.6000
Enth MMBtu/min	-0.010643	-0.013775
Vapor mass fraction	1.0000	1.0000
Total lb/min	326.0000	418.4000
Flowrates in lb/min		
Nitrogen	248.7466	319.2233
Oxygen	75.5285	96.9135
Water	1.7211	2.2131
Sulfur Dioxide	0.0000	0.0463
Hydrogen Sulfide	0.0038	0.0038
Sulphur	0.0000	0.0000
Hydrogen	0.0000	0.0000
Sulfuric Acid	0.0000	0.0000

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Job Name: wvaIWTPl-3 Date: 08/28/2001 Time: 09:06:29

Electrolyte Compositions

Stream No.	1	2	3	4
Stream Name	RCTR VENT	TWR LQR	SCRBR RCYCL	MAKE-UP WTR
Temp F	68.0000	55.2661	54.1434	70.0000
Pres psia	14.6000	14.5000	34.5000	14.9000
Ph value	0.0000	3.0113	2.9825	7.0643
Ionic strength molal	0.0000	0.0010	0.0010	0.0000
Flowrates in lb/min				
H2O	0.0000	493.9076	458.9076	35.0000
H+	0.0000	0.0005	0.0005	0.0000
OH-	0.0000	0.0000	0.0000	0.0000
H2S	0.0000	0.0000	0.0000	0.0000
HS-	0.0000	0.0000	0.0000	0.0000
S--	0.0000	0.0000	0.0000	0.0000
SO2	0.0000	0.0029	0.0031	0.0000
SO3--	0.0000	0.0000	0.0000	0.0000
HSO3-	0.0000	0.0390	0.0387	0.0000
H2SO4	0.0000	0.0000	0.0000	0.0000
HSO4-	0.0000	0.0000	0.0000	0.0000
SO4--	0.0000	0.0000	0.0000	0.0000

Stream No.	5	6	7	8
Stream Name	STACK	Bottoms	Pmp Dsch	Blowdown
Temp F	55.1315	54.0649	54.1434	54.1434
Pres psia	14.5000	14.5000	34.5000	34.5000
Ph value	0.0000	2.9823	2.9825	2.9825
Ionic strength molal	0.0000	0.0010	0.0010	0.0010
Flowrates in lb/min				
H2O	0.0000	492.1859	492.1859	33.2783
H+	0.0000	0.0005	0.0005	0.0000
OH-	0.0000	0.0000	0.0000	0.0000
H2S	0.0000	0.0000	0.0000	0.0000
HS-	0.0000	0.0000	0.0000	0.0000
S--	0.0000	0.0000	0.0000	0.0000
SO2	0.0000	0.0033	0.0033	0.0002
SO3--	0.0000	0.0000	0.0000	0.0000
HSO3-	0.0000	0.0416	0.0415	0.0028
H2SO4	0.0000	0.0000	0.0000	0.0000
HSO4-	0.0000	0.0000	0.0000	0.0000
SO4--	0.0000	0.0000	0.0000	0.0000

Stream No.	9	10
Stream Name	BL/CLAR VNT	
Temp F	68.0000	68.0000
Pres psia	14.6000	14.6000
Ph value	0.0000	0.0000
Ionic strength molal	0.0000	0.0000
Flowrates in lb/min		
H2O	0.0000	0.0000
H+	0.0000	0.0000
OH-	0.0000	0.0000
H2S	0.0000	0.0000
HS-	0.0000	0.0000
S--	0.0000	0.0000
SO2	0.0000	0.0000

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Job Name: wvaIWTP1-3 Date: 08/28/2001 Time: 09:06:29
Electrolyte Compositions

SO3--	0.0000	0.0000
HSO3-	0.0000	0.0000
H2SO4	0.0000	0.0000
HSO4-	0.0000	0.0000
SO4--	0.0000	0.0000

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Job Name: wvaIWTP1-3 Date: 08/28/2001 Time: 09:06:29

DISTILLATION PROFILE

Unit type : SCDS Unit name: Eqp # 5

Stg	Temp	Pres	* Net Flows *		Feeds	Product	Duties
	F	psia	Liquid lbmol/min	Vapor lbmol/min			
1	55.1	14.50	27.42		27.42	14.64	
2	55.1	14.50	27.42	14.64			
3	55.0	14.50	27.42	14.64			
4	54.9	14.50	27.41	14.64			
5	54.6	14.50	27.41	14.64			
6	54.1	14.50		14.63	14.55	27.32	

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Job Name: wvaIWTF1-3 Date: 08/28/2001 Time: 09:06:29

DISTILLATION PROFILE

Unit type : SCDS Unit name: Eqp # 5

Stg	Temp	Pres	* Net Flows *		Feeds	Product	Duties
	F	psia	Liquid lb/min	Vapor lb/min			
1	55.1	14.50	493.96		493.96	420.12	
2	55.1	14.50	493.95	420.11			
3	55.0	14.50	493.93	420.10			
4	54.9	14.50	493.89	420.08			
5	54.6	14.50	493.81	420.04			
6	54.1	14.50		419.97	418.40	492.25	

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Page 1

Job Name: WVAIWTP1-7 Date: 01/22/2002 Time: 08:51:08

FLOWSHEET SUMMARY

Equipment	Label	Stream Numbers
1 MIXE		1 9 -10
2 MIXE		4 10 -12
3 PUMP		6 -7
4 DIVI		7 -3 -8
5 SCDS		2 12 -5 -6
6 MIXE		3 11 -2

Stream Connections

Stream	Equipment From To	Stream	Equipment From To	Stream	Equipment From To
1	6 1	5	5 5	9	1 1
2	5 5	6	5 3	10	1 2
3	4 6	7	3 4	11	6 6
4	2 2	8	4 4	12	2 5

Calculation mode : Sequential
Flash algorithm : Electrolyte

Equipment Calculation Sequence
1 2 5 3 4 6

Equipment Recycle Sequence
5 3 4 6

Recycle Cut Streams
2

Recycle Convergence Method: Wegstein

Wegstein lower bound -5.00 Wegstein upper bound 0.00
Acceleration frequency 4
Max. loop iterations 100
Flash Damping factor 0.30

Recycle Convergence Tolerance

Flow rate 5.000E-004
Temperature 1.000E-003
Pressure 1.000E-003
Enthalpy 1.000E-003
Vapor frac. 1.000E-003

Recycle calculation has converged.

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Job Name: WVAIWTP1-7 Date: 01/22/2002 Time: 08:51:08

COMPONENTS

	ID #	Name
1	46	Nitrogen
2	47	Oxygen
3	62	Water
4	51	Sulfur Dioxide
5	50	Hydrogen Sulfide
6	992	Sulphur
7	1	Hydrogen
8	431	Sulfuric Acid
9	429	Sodium Hydroxide

THERMODYNAMICS

K-value model : NRTL
 No correction for vapor fugacity
 Enthalpy model : Latent Heat
 Liquid density : Library

NRTL Parameters:

I	J	Bij	Bji	Alpha	Aij	Aji
3	4	-372.398	2383.660	0.104	0.000	0.000
3	8	-1228.660	-1894.250	0.243	0.000	0.000

Warning : BIP matrix is less than 50 % full.

ELECTROLYTE DATA INPUT

Electrolyte model: NRTL

	ID #	Species
1	1005	H2O
2	1002	H+
3	1004	OH-
4	1029	H2S
5	1028	HS-
6	1024	S--
7	1025	SO2
8	1026	SO3--
9	1030	HSO3-
10	1199	NaOH
11	1198	Na+
12	1033	H2SO4
13	1031	HSO4-
14	1027	SO4--

No. of reactions 8

Reaction Stoichiometrics and Parameters:

Reaction $\ln K = A + B / T + C \ln T + D * T + E * T * T$; T, deg K

Reaction 1 Base = Molal

A	B	C	D	E
---	---	---	---	---

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Job Name: WVAIWTP1-7 Date: 01/22/2002 Time: 08:51:08

1.4093e+002 -1.3446e+004 -2.2477e+001 0.0000e+000 0.0000e+000

Species	Stoichiometrics	Form
1	-1.0	H2O
2	1.0	H+
3	1.0	OH-

Reaction 2 Base = Molal

A	B	C	D	E
-7.4890e+000	-7.2112e+003	0.0000e+000	0.0000e+000	0.0000e+000

Species	Stoichiometrics	Form
5	-1.0	HS-
2	1.0	H+
6	1.0	S--

Reaction 3 Base = Molal

A	B	C	D	E
2.1860e+002	-1.2995e+004	-3.3547e+001	0.0000e+000	0.0000e+000

Species	Stoichiometrics	Form
4	-1.0	H2S
2	1.0	H+
5	1.0	HS-

Reaction 4 Base = Molal

A	B	C	D	E
-1.9621e+000	6.3740e+002	0.0000e+000	-1.5134e-002	0.0000e+000

Species	Stoichiometrics	Form
7	-1.0	SO2
1	-1.0	H2O
2	1.0	H+
9	1.0	HSO3-

Reaction 5 Base = Molal

A	B	C	D	E
-2.1274e+001	1.3334e+003	0.0000e+000	0.0000e+000	0.0000e+000

Species	Stoichiometrics	Form
9	-1.0	HSO3-
2	1.0	H+
8	1.0	SO3--

Reaction 6 Base = Molal

A	B	C	D	E
0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000

Species	Stoichiometrics	Form
12	-1.0	H2SO4
13	1.0	HSO4-
2	1.0	H+

Reaction 7 Base = Molal

A	B	C	D	E
9.5465e+000	-7.3337e+002	0.0000e+000	-3.8845e-002	0.0000e+000

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Job Name: WVAIWTP1-7 Date: 01/22/2002 Time: 08:51:08

Species	Stoichiometrics	Form
13	-1.0	HSO4-
2	1.0	H+
14	1.0	SO4--

Reaction 8 Base = Molal

A	B	C	D	E
0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000

Species	Stoichiometrics	Form
10	-1.0	NaOH
11	1.0	Na+
3	1.0	OH-

Henry's Constants: $\ln H = A + B / T + C \ln T + D * T$
 $H = \text{kg-atm/mole}; T, \text{deg K}$

	A	B	C	D
2 Oxygen	1.0459e+001	-1.0854e+003	0.0000e+000	0.0000e+000
4 Sulfur Dioxide	6.8418e+001	-5.5788e+003	-8.7615e+000	0.0000e+000
5 Hydrogen Sulfide	3.4260e+002	-1.3237e+004	-5.5055e+001	5.9565e-002
8 Sulfuric Acid	-4.8528e+000	-6.3972e+003	1.9016e+000	0.0000e+000

Electrolyte NRTL parameters

IDi	IDj	TijA	TijB	TjiA	TjiB	Alpha
1005	1025	-29.976	-3371	-2.055	2459.7	0.13977
1005	1029	-3.674	1155.9	-3.674	1155.9	0.2
1005	1033	-7.12029	696.966	3.56505	1357.61	0.113532

IDm	IDc	IDa	TmcaA	TmcaB	TmcaC	TcamA	TcamB	TcamC	Alpha
1005	1002	1030	19.685	1987.7	0	-19.389	1404.3	0	0.22164
1005	1002	1031	-13.4684	-1124.41	40.0089	7.69427	-3008.13	-30.468	0.076502
1005	1002	1027	0.815756	-1749.8	0	-4.45807	280.289	0	0.148914
1005	1198	1004	-34.9707	12492.2	-99.873	9.198	-3988.5	-34.386	0.2
1005	1198	1031	7.663	0	0	-3.944	0	0	0.2
1005	1198	1027	8.389	0	0	-4.539	0	0	0.2
1033	1002	1031	5.9709	0	0	-9.7482	0	0	0.2

Electrolyte enthalpy model.

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Job Name: WVAIWTP1-7 Date: 01/22/2002 Time: 08:51:08

Overall Mass Balance	lbmol/min		lb/min	
	Input	Output	Input	Output
Nitrogen	11.395	11.395	319.223	319.223
Oxygen	3.029	3.029	96.914	96.914
Water	1.785	1.785	32.152	32.161
Sulfur Dioxide	0.001	0.001	0.070	0.069
Hydrogen Sulfide	0.000	0.000	0.005	0.005
Sulphur	0.000	0.000	0.000	0.000
Hydrogen	0.000	0.000	0.000	0.000
Sulfuric Acid	0.000	0.000	0.000	0.000
Sodium Hydroxide	0.005	0.005	0.185	0.183
Total	16.214	16.215	448.548	448.555

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Job Name: WVAIWTP1-7 Date: 01/22/2002 Time: 08:51:08
EQUIPMENT SUMMARIES

Mixer Summary

Equip. No.	1	2	6
Name			

Pump Summary

Equip. No.	3
Name	
Pressure increase psi	55.0000
Efficiency	0.7500
Calculated power hp	4.4074
Calculated Pout psia	69.5000
Head ft	125.8733
Vol. flow rate gpm	102.9720

Divider Summary

Equip. No.	4
Name	
Split based on	4
Output stream #1	100.0000
Flow rate units	9

Scds Rigorous Distillation Summary

Equip. No.	5
Name	
No. of stages	2
1st feed stage	1
2nd feed stage	2
Est. dist. rate (lbmol/min)	14.4000
Est. stage 1 T F	55.0000
Est. bottom T F	55.0000
Top pressure psia	14.5000
Reflux mole lbmol/min	46.2930
Reflux mass lb/min	838.5380

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Job Name: WVAIWTP1-7 Date: 01/22/2002 Time: 08:51:08

STREAM PROPERTIES

Stream No.	1	2	3	4
Name	RCRTR VENT	TWR LQR	SCRBR RCYCL	MAKE-UP WTR
- - Overall - -				
Molar flow lbmol/min	3.2125	46.2940	46.2484	1.6209
Mass flow lb/min	92.4232	838.5579	837.6344	29.2000
Temp F	68.0000	55.9316	55.9191	70.0000
Pres psia	14.6000	14.9000	69.5000	14.9000
Vapor mole fraction	1.000	0.0000	0.0000	0.0000
Enth MMBtu/min	-0.0031788	-5.7194	-5.7134	-0.19939
Tc F	-217.1528	741.9117	740.7337	705.5600
Pc psia	518.7978	3718.3279	3702.0081	3207.9768
Std. sp gr. air = 1	0.993	0.625	0.625	0.622
Degree API	31.7671	9.3450	9.3595	9.8949
Average mol wt	28.7702	18.1137	18.1117	18.0150
Actual dens lb/ft3	0.0742	62.9371	62.9195	62.2789
Actual vol ft3/min	1245.4826	13.3238	13.3128	0.4689
Std vap 60F scfm	1219.0617	17567.5833	17550.2687	615.0861
- - Vapor only - -				
Molar flow lbmol/min	3.2125			
Mass flow lb/min	92.4232			
Average mol wt	28.7702			
Actual dens lb/ft3	0.0742			
Actual vol ft3/min	1245.4826			
Std liq gpm	12.7914			
Std vap 60F scfm	1219.0617			
Cp Btu/lb-F	0.2432			
Z factor	0.9997			
Visc lbm/ft-hr	0.04350			
Th cond Btu/hr-ft-F	0.0145			
- - Liquid only - -				
Molar flow lbmol/min		46.2940	46.2484	1.6209
Mass flow lb/min		838.5579	837.6344	29.2000
Average mol wt		18.1137	18.1117	18.0150
Actual dens lb/ft3		62.9371	62.9195	62.2789
Actual vol gpm		99.6800	99.5981	3.5077
Std vap 60F scfm		17567.5833	17550.2687	615.0861
Cp Btu/lb-F		0.9966	0.9965	1.0000
Z factor		0.0010	0.0048	0.0010
Visc lbm/ft-hr		3.028	3.025	2.436
Th cond Btu/hr-ft-F		0.3390	0.3390	0.3470
Surf tens dyne/cm		74.6136	74.5935	72.7749

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Job Name: VVAIWTP1-7 Date: 01/22/2002 Time: 08:51:08

STREAM PROPERTIES

Stream No.	5	6	7	8
Name	STACK	Bottoms	Pmp Dsch	Blowdown
- - Overall - -				
Molar flow lbmol/min	14.6474	47.8158	47.8158	1.5674
Mass flow lb/min	420.1664	866.0230	866.0230	28.3886
Temp F	55.9009	55.7124	55.9191	55.9191
Pres psia	14.5000	14.5000	69.5000	69.5000
Vapor mole fraction	1.000	0.0000	0.0000	0.0000
Enth MMBtu/min	-0.025403	-5.9072	-5.9070	-0.19364
Tc F	-212.7067	740.7337	740.7337	740.7337
Pc psia	513.1857	3702.0081	3702.0081	3702.0105
Std. sp gr. air = 1	0.990	0.625	0.625	0.625
Degree API	31.7171	9.3595	9.3595	9.3595
Average mol wt	28.6854	18.1117	18.1117	18.1117
Actual dens lb/ft3	0.0752	62.9204	62.9195	62.9195
Actual vol ft3/min	5586.2339	13.7638	13.7640	0.4512
Std vap 60F scfm	5558.3750	18145.0729	18145.0729	594.8029
- - Vapor only - -				
Molar flow lbmol/min	14.6474			
Mass flow lb/min	420.1664			
Average mol wt	28.6854			
Actual dens lb/ft3	0.0752			
Actual vol ft3/min	5586.2339			
Std liq gpm	58.1334			
Std vap 60F scfm	5558.3750			
Cp Btu/lb-F	0.2441			
Z factor	0.9996			
Visc lbm/ft-hr	0.04256			
Th cond Btu/h-ft-F	0.0142			
- - Liquid only - -				
Molar flow lbmol/min		47.8158	47.8158	1.5674
Mass flow lb/min		866.0230	866.0230	28.3886
Average mol wt		18.1117	18.1117	18.1117
Actual dens lb/ft3		62.9204	62.9195	62.9195
Actual vol gpm		102.9720	102.9736	3.3755
Std vap 60F scfm		18145.0729	18145.0729	594.8029
Cp Btu/lb-F		0.9958	0.9958	0.9969
Z factor		0.0010	0.0048	0.0048
Visc lbm/ft-hr		3.032	3.025	3.025
Th cond Btu/hr-ft-F		0.3389	0.3390	0.3390
Surf tens dyne/cm		74.6134	74.5935	74.5935

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Job Name: WVAIWTP1-7 Date: 01/22/2002 Time: 08:51:09
 STREAM PROPERTIES

Stream No.	9	10	11	12
Name	BL/CLAR VNT	comb. vents	CAUSTIC	
- - Overall - -				
Molar flow lbmol/min	11.3354	14.5479	0.0456	16.1687
Mass flow lb/min	326.0011	418.4243	0.9235	447.6243
Temp F	68.0000	68.0000	70.0000	54.9294
Pres psia	14.6000	14.6000	14.9000	14.6000
Vapor mole fraction	1.000	1.000	0.0000	0.9055
Enth MMBtu/min	-0.010643	-0.013822	-0.0059778	-0.21321
Tc F	-217.4516	-217.3856	1729.4841	-146.6474
Pc psia	517.5844	517.8527	13545.5986	453.1258
Std. sp gr. air = 1	0.993	0.993	0.699	0.956
Degree API	31.8112	31.8015	-3.7643	30.3724
Average mol wt	28.7596	28.7619	20.2397	27.6846
Actual dens lb/ft3	0.0742	0.0742	76.0296	0.0809
Actual vol ft3/min	4394.7760	5640.2583	0.0121	5535.2207
Std vap 60F scfm	4301.5380	5520.5995	17.3154	6135.6854
- - Vapor only - -				
Molar flow lbmol/min	11.3354	14.5479		14.6402
Mass flow lb/min	326.0011	418.4243		420.0863
Average mol wt	28.7596	28.7619		28.6940
Actual dens lb/ft3	0.0742	0.0742		0.0759
Actual vol ft3/min	4394.7760	5640.2583		5534.7792
Std liq gpm	45.1309	57.9223		58.1216
Std vap 60F scfm	4301.5380	5520.5995		5555.6536
Cp Btu/lb-F	0.2432	0.2432		0.2440
Z factor	0.9997	0.9997		0.9996
Visc lbm/ft-hr	0.04351	0.04351		0.04251
Th cond Btu/hr-ft-F	0.0145	0.0145		0.0142
- - Liquid only - -				
Molar flow lbmol/min			0.0456	1.5285
Mass flow lb/min			0.9235	27.5380
Average mol wt			20.2397	18.0164
Actual dens lb/ft3			76.0296	62.3717
Actual vol gpm			0.0909	3.3031
Std vap 60F scfm			17.3154	580.0316
Cp Btu/lb-F			0.8702	1.0029
Z factor			0.0012	0.0010
Visc lbm/ft-hr			8.986	2.973
Th cond Btu/hr-ft-F			0.3277	0.3397
Surf tens dyne/cm			96.7316	74.1940

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Job Name: WVAIWTP1-7 Date: 01/22/2002 Time: 08:51:09
FLOW SUMMARIES

Stream No.	1	2	3	4
Stream Name	RCTR VENT	TWR LQR	SCRBR RCYCL	MAKE-UP WTR
Temp F	68.0000	55.9316	55.9191	70.0000
Pres psia	14.6000	14.9000	69.5000	14.9000
Enth MMBtu/min	-0.0031788	-5.7194	-5.7134	-0.19939
Vapor mole fraction	1.0000	0.00000	0.00000	0.00000
Total lbmol/min	3.2125	46.2940	46.2484	1.6209
Flowrates in lbmol/min				
Nitrogen	2.5158	0.0005	0.0005	0.0000
Oxygen	0.6683	0.0003	0.0003	0.0000
Water	0.0273	46.1184	46.0774	1.6209
Sulfur Dioxide	0.0011	0.0309	0.0309	0.0000
Hydrogen Sulfide	0.0000	0.0041	0.0041	0.0000
Sulphur	0.0000	0.0000	0.0000	0.0000
Hydrogen	0.0000	0.0000	0.0000	0.0000
Sulfuric Acid	0.0000	0.0000	0.0000	0.0000
Sodium Hydroxide	0.0000	0.1398	0.1352	0.0000

Stream No.	5	6	7	8
Stream Name	STACK	Bottoms	Pmp Dsch	Blowdown
Temp F	55.9009	55.7124	55.9191	55.9191
Pres psia	14.5000	14.5000	69.5000	69.5000
Enth MMBtu/min	-0.025403	-5.9072	-5.9070	-0.19364
Vapor mole fraction	1.0000	0.00000	0.00000	0.00000
Total lbmol/min	14.6474	47.8158	47.8158	1.5674
Flowrates in lbmol/min				
Nitrogen	11.3951	0.0005	0.0005	0.0000
Oxygen	3.0286	0.0003	0.0003	0.0000
Water	0.2236	47.6390	47.6390	1.5616
Sulfur Dioxide	0.0000	0.0320	0.0320	0.0010
Hydrogen Sulfide	0.0000	0.0042	0.0042	0.0001
Sulphur	0.0000	0.0000	0.0000	0.0000
Hydrogen	0.0000	0.0000	0.0000	0.0000
Sulfuric Acid	0.0000	0.0000	0.0000	0.0000
Sodium Hydroxide	0.0000	0.1398	0.1398	0.0046

Stream No.	9	10	11	12
Stream Name	BL/CLAR VNT	comb. vents	CAUSTIC	
Temp F	68.0000	68.0000	70.0000	54.9294
Pres psia	14.6000	14.6000	14.9000	14.6000
Enth MMBtu/min	-0.010643	-0.013822	-0.0059778	-0.21321
Vapor mole fraction	1.0000	1.0000	0.00000	0.90547
Total lbmol/min	11.3354	14.5479	0.0456	16.1687
Flowrates in lbmol/min				
Nitrogen	8.8794	11.3951	0.0000	11.3951
Oxygen	2.3603	3.0286	0.0000	3.0286
Water	0.0955	0.1228	0.0410	1.7437
Sulfur Dioxide	0.0000	0.0011	0.0000	0.0011
Hydrogen Sulfide	0.0001	0.0001	0.0000	0.0001
Sulphur	0.0000	0.0000	0.0000	0.0000
Hydrogen	0.0000	0.0000	0.0000	0.0000
Sulfuric Acid	0.0000	0.0000	0.0000	0.0000
Sodium Hydroxide	0.0000	0.0000	0.0046	0.0000

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Job Name: WVAIWTP1-7 Date: 01/22/2002 Time: 08:51:09
Electrolyte Compositions

Stream No.	1	2	3	4
Stream Name	RCTR VENT	TWR LQR	SCRBR RCYCL	MAKE-UP WTR
Temp F	68.0000	55.9316	55.9191	70.0000
Pres psia	14.6000	14.9000	69.5000	14.9000
Ph value	0.0000	13.0922	13.0655	7.0643
Ionic strength molal	0.0000	0.2066	0.2011	0.0000
Flowrates in lbmol/min				
H2O	0.0000	46.1545	46.1134	1.6209
H+	0.0000	0.0000	0.0000	0.0000
OH-	0.0000	0.0728	0.0683	0.0000
H2S	0.0000	0.0000	0.0000	0.0000
HS-	0.0000	0.0030	0.0031	0.0000
S--	0.0000	0.0010	0.0010	0.0000
SO2	0.0000	0.0000	0.0000	0.0000
SO3--	0.0000	0.0309	0.0309	0.0000
HSO3-	0.0000	0.0000	0.0000	0.0000
NaOH	0.0000	0.0000	0.0000	0.0000
Na+	0.0000	0.1398	0.1352	0.0000
H2SO4	0.0000	0.0000	0.0000	0.0000
HSO4-	0.0000	0.0000	0.0000	0.0000
SO4--	0.0000	0.0000	0.0000	0.0000

Stream No.	5	6	7	8
Stream Name	STACK	Bottoms	Pmp Dsch	Blowdown
Temp F	55.9009	55.7124	55.9191	55.9191
Pres psia	14.5000	14.5000	69.5000	69.5000
Ph value	0.0000	13.0698	13.0655	13.0655
Ionic strength molal	0.0000	0.2011	0.2011	0.2011
Flowrates in lbmol/min				
H2O	0.0000	47.6763	47.6763	1.5628
H+	0.0000	0.0000	0.0000	0.0000
OH-	0.0000	0.0706	0.0706	0.0023
H2S	0.0000	0.0000	0.0000	0.0000
HS-	0.0000	0.0032	0.0032	0.0001
S--	0.0000	0.0010	0.0010	0.0000
SO2	0.0000	0.0000	0.0000	0.0000
SO3--	0.0000	0.0320	0.0320	0.0010
HSO3-	0.0000	0.0000	0.0000	0.0000
NaOH	0.0000	0.0000	0.0000	0.0000
Na+	0.0000	0.1398	0.1398	0.0046
H2SO4	0.0000	0.0000	0.0000	0.0000
HSO4-	0.0000	0.0000	0.0000	0.0000
SO4--	0.0000	0.0000	0.0000	0.0000

Stream No.	9	10	11	12
Stream Name	BL/CLAR VNT	comb. vents	CAUSTIC	
Temp F	68.0000	68.0000	70.0000	54.9294
Pres psia	14.6000	14.6000	14.9000	14.6000
Ph value	0.0000	0.0000	15.4021	2.8707
Ionic strength molal	0.0000	0.0000	6.2504	0.0013
Flowrates in lbmol/min				
H2O	0.0000	0.0000	0.0410	1.5284
H+	0.0000	0.0000	0.0000	0.0000
OH-	0.0000	0.0000	0.0046	0.0000

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Job Name: WVAIWTP1-7 Date: 01/22/2002 Time: 08:51:09

Electrolyte Compositions

H2S	0.0000	0.0000	0.0000	0.0000
HS-	0.0000	0.0000	0.0000	0.0000
S--	0.0000	0.0000	0.0000	0.0000
SO2	0.0000	0.0000	0.0000	0.0000
SO3--	0.0000	0.0000	0.0000	0.0000
HSO3-	0.0000	0.0000	0.0000	0.0000
NaOH	0.0000	0.0000	0.0000	0.0000
Na+	0.0000	0.0000	0.0046	0.0000
H2SO4	0.0000	0.0000	0.0000	0.0000
HSO4-	0.0000	0.0000	0.0000	0.0000
SO4--	0.0000	0.0000	0.0000	0.0000

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Job Name: WVAIWTP1-7 Date: 01/22/2002 Time: 08:51:09
 FLOW SUMMARIES

Stream No.	1	2	3	4
Stream Name	RCTR VENT	TWR LQR	SCRBR RCYCL	MAKE-UP WTR
Temp F	68.0000	55.9316	55.9191	70.0000
Pres psia	14.6000	14.9000	69.5000	14.9000
Enth MMBtu/min	-0.0031788	-5.7194	-5.7134	-0.19939
Vapor mass fraction	1.0000	0.00000	0.00000	0.00000
Total lb/min	92.4232	838.5579	837.6344	29.2000
Flowrates in lb/min				
Nitrogen	70.4767	0.0140	0.0140	0.0000
Oxygen	21.3850	0.0086	0.0086	0.0000
Water	0.4920	830.8234	830.0846	29.2000
Sulfur Dioxide	0.0695	1.9811	1.9811	0.0000
Hydrogen Sulfide	0.0000	0.1392	0.1392	0.0000
Sulphur	0.0000	0.0000	0.0000	0.0000
Hydrogen	0.0000	0.0000	0.0000	0.0000
Sulfuric Acid	0.0000	0.0000	0.0000	0.0000
Sodium Hydroxide	0.0000	5.5916	5.4069	0.0000

Stream No.	5	6	7	8
Stream Name	STACK	Bottoms	Pmp Dsch	Blowdown
Temp F	55.9009	55.7124	55.9191	55.9191
Pres psia	14.5000	14.5000	69.5000	69.5000
Enth MMBtu/min	-0.025403	-5.9072	-5.9070	-0.19364
Vapor mass fraction	1.0000	0.00000	0.00000	0.00000
Total lb/min	420.1664	866.0230	866.0230	28.3886
Flowrates in lb/min				
Nitrogen	319.2229	0.0144	0.0144	0.0005
Oxygen	96.9132	0.0089	0.0089	0.0003
Water	4.0285	858.2174	858.2174	28.1327
Sulfur Dioxide	0.0018	2.0483	2.0483	0.0671
Hydrogen Sulfide	0.0001	0.1439	0.1439	0.0047
Sulphur	0.0000	0.0000	0.0000	0.0000
Hydrogen	0.0000	0.0000	0.0000	0.0000
Sulfuric Acid	0.0000	0.0000	0.0000	0.0000
Sodium Hydroxide	0.0000	5.5901	5.5901	0.1832

Stream No.	9	10	11	12
Stream Name	BL/CLAR VNT	comb. vents	CAUSTIC	
Temp F	68.0000	68.0000	70.0000	54.9294
Pres psia	14.6000	14.6000	14.9000	14.6000
Enth MMBtu/min	-0.010643	-0.013822	-0.0059778	-0.21321
Vapor mass fraction	1.0000	1.0000	0.00000	0.93848
Total lb/min	326.0011	418.4243	0.9235	447.6243
Flowrates in lb/min				
Nitrogen	248.7466	319.2233	0.0000	319.2233
Oxygen	75.5285	96.9135	0.0000	96.9135
Water	1.7211	2.2131	0.7388	31.4131
Sulfur Dioxide	0.0000	0.0695	0.0000	0.0695
Hydrogen Sulfide	0.0050	0.0050	0.0000	0.0050
Sulphur	0.0000	0.0000	0.0000	0.0000
Hydrogen	0.0000	0.0000	0.0000	0.0000
Sulfuric Acid	0.0000	0.0000	0.0000	0.0000
Sodium Hydroxide	0.0000	0.0000	0.1847	0.0000

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Job Name: WVAIWTP1-7 Date: 01/22/2002 Time: 08:51:09
Electrolyte Compositions

Stream No.	1	2	3	4
Stream Name	RCTR VENT	TWR LQR	SCRBR RCYCL	MAKE-UP WTR
Temp F	68.0000	55.9316	55.9191	70.0000
Pres psia	14.6000	14.9000	69.5000	14.9000
Ph value	0.0000	13.0922	13.0655	7.0643
Ionic strength molal	0.0000	0.2066	0.2011	0.0000
Flowrates in lb/min				
H2O	0.0000	831.4729	830.7330	29.2000
H+	0.0000	0.0000	0.0000	0.0000
OH-	0.0000	1.2386	1.1611	0.0000
H2S	0.0000	0.0000	0.0000	0.0000
HS-	0.0000	0.1008	0.1027	0.0000
S--	0.0000	0.0333	0.0314	0.0000
SO2	0.0000	0.0000	0.0000	0.0000
SO3--	0.0000	2.4758	2.4758	0.0000
HSO3-	0.0000	0.0000	0.0000	0.0000
NaOH	0.0000	0.0000	0.0000	0.0000
Na+	0.0000	3.2140	3.1078	0.0000
H2SO4	0.0000	0.0000	0.0000	0.0000
HSO4-	0.0000	0.0000	0.0000	0.0000
SO4--	0.0000	0.0000	0.0000	0.0000

Stream No.	5	6	7	8
Stream Name	STACK	Bottoms	Pmp Dsch	Blowdown
Temp F	55.9009	55.7124	55.9191	55.9191
Pres psia	14.5000	14.5000	69.5000	69.5000
Ph value	0.0000	13.0698	13.0655	13.0655
Ionic strength molal	0.0000	0.2011	0.2011	0.2011
Flowrates in lb/min				
H2O	0.0000	858.8877	858.8877	28.1547
H+	0.0000	0.0000	0.0000	0.0000
OH-	0.0000	1.2004	1.2004	0.0393
H2S	0.0000	0.0000	0.0000	0.0000
HS-	0.0000	0.1062	0.1062	0.0035
S--	0.0000	0.0325	0.0325	0.0011
SO2	0.0000	0.0000	0.0000	0.0000
SO3--	0.0000	2.5598	2.5598	0.0839
HSO3-	0.0000	0.0000	0.0000	0.0000
NaOH	0.0000	0.0000	0.0000	0.0000
Na+	0.0000	3.2132	3.2132	0.1053
H2SO4	0.0000	0.0000	0.0000	0.0000
HSO4-	0.0000	0.0000	0.0000	0.0000
SO4--	0.0000	0.0000	0.0000	0.0000

Stream No.	9	10	11	12
Stream Name	BL/CLAR VNT	comb. vents	CAUSTIC	
Temp F	68.0000	68.0000	70.0000	54.9294
Pres psia	14.6000	14.6000	14.9000	14.6000
Ph value	0.0000	0.0000	15.4021	2.8707
Ionic strength molal	0.0000	0.0000	6.2504	0.0013
Flowrates in lb/min				
H2O	0.0000	0.0000	0.7388	27.5339
H+	0.0000	0.0000	0.0000	0.0000
OH-	0.0000	0.0000	0.0785	0.0000

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Job Name: WVAIWTP1-7 Date: 01/22/2002 Time: 08:51:09

Electrolyte Compositions

H2S	0.0000	0.0000	0.0000	0.0000
HS-	0.0000	0.0000	0.0000	0.0000
S--	0.0000	0.0000	0.0000	0.0000
SO2	0.0000	0.0000	0.0000	0.0004
SO3--	0.0000	0.0000	0.0000	0.0000
HSO3-	0.0000	0.0000	0.0000	0.0030
NaOH	0.0000	0.0000	0.0000	0.0000
Na+	0.0000	0.0000	0.1062	0.0000
H2SO4	0.0000	0.0000	0.0000	0.0000
HSO4-	0.0000	0.0000	0.0000	0.0000
SO4--	0.0000	0.0000	0.0000	0.0000

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Job Name: WVAIWTP1-7 Date: 01/22/2002 Time: 08:51:09
DISTILLATION PROFILE

Unit type : SCDS Unit name: Eqp # 5

Stg	Temp	Pres	* Net Flows *		Feeds	Product	Duties
	F	psia	Liquid lbmol/min	Vapor lbmol/min	lbmol/min	lbmol/min	MMBtu/min
1	55.9	14.50	46.29		46.29	14.65	
2	55.7	14.50		14.65	16.17	47.82	

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Job Name: WVAIWTP1-7 Date: 01/22/2002 Time: 08:51:09
DISTILLATION PROFILE

Unit type : SCDS Unit name: Eqp # 5

Stg	Temp	Pres	* Net Flows *		Feeds	Product	Duties
	F	psia	Liquid lb/min	Vapor lb/min	lb/min	lb/min	MMBtu/min
1	55.9	14.50	838.54		838.56	420.17	
2	55.7	14.50		420.14	447.62	866.02	

WET SCRUBBERS

SECOND EDITION

Kenneth C. Schifftner
Howard E. Hesketh

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changes of direction of the gas stream. These units behave very well where throat velocities of over 200 ft/min are needed.

Another venturi scrubber design that seeks to limit the throat width to improve particulate capture is the Narrow Gap Venturi (NGV) scrubber (Figure 1.14b). This patented design uses a group of parallel fixed flat plates that divide the scrubber throat into zones. These zones are typically 1 in. to 2 in. wide. To make the unit adjustable, a pivoting set of similarly parallel blades are arranged such that they swing into the gap between the fixed blades. This arrangement is much like the design of an old tuning capacitor in a radio. As the movable blades swing into the throat zone, they decrease the throat area, increase the wetted surface, and decrease the throat gap further. This combination of events serves to change the hydraulic diameter of the throat and therefore change the throat pressure drop.

Either venturi type may have a wet or a dry "approach." This term applies to the hopper-like transition of the inlet to the throat area. Usually, the inlet spool extends into the venturi, thus avoiding "wet/dry line buildup." Whenever a surface is only partially wetted, the airborne dust will build up. Dry dust tends to seek areas of higher humidity, especially if the dust is hygroscopic. The inlet spool extension reduces this tendency.

By totally wetting the approach in dentist-bowl fashion or through the use of weirs, the wet/dry line can be controlled. Designs which rely on spray nozzles to accomplish this needed feature are inferior to designs of simple execution.

Venturi liquid rates range from 4 to over 100 gal/1000 acf. Spray-augmented venturis use lower rates, in general, than hydraulically atomized designs, but are more prone to nozzle plugging. Tangential inlet liquid velocities in annular designs are approximately 6–8 ft/sec for coverage of the dentist-bowl approach and header pressures of 5–10 psig are used for spray wetting. A variation of this type is the Peabody radial scrubber, shown in Figure 1.15.

Venturi scrubbers are in operation at over 100 in. w.c. pressure drops, at pressures of –100 in. w.c. to hundreds of psig.

Variations include eductor designs such as those manufactured by Shuttle and Koerting and Croll-Reynolds, and charge-enhanced designs such as the Pilat® scrubber.

1.4.5 Augmented Scrubbers (Electrostatically Enhanced)

In a high-energy venturi, we have reached the practical limits of inertial-based removal techniques because our target particles, the submicron species, behave as if they have little or no mass. Other forces have been shown to be more effective on these particulates; the most prominent is electrostatic attraction.

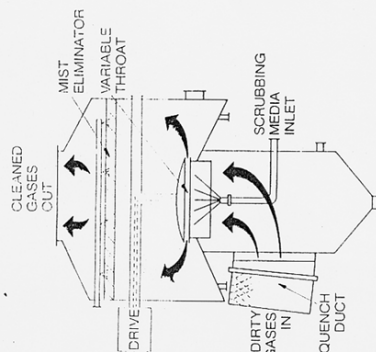


FIGURE 1.15. Schematic of Peabody Lurgi design up-flow radial scrubber (courtesy Peabody Engineering Corporation).

In this method, a conventional scrubber has its removal efficiency enhanced through the application of a positive charge to the incoming contaminant stream. Since the water tends to be electronegative, the small particulate is attracted to the water by electrostatic forces. Given the fact that water is a polar molecule, the tendency for water to act as a ground is not a pronounced one. This has led to developmental difficulties in the charge-augmented designs: one wants to charge the particulate but not the water.

Other designs, such as TRW's wet electrostatic precipitator, attempt to charge the water, introducing it as a charged spray wherein it migrates to a collecting electrode. Another design passes the contaminant stream through a carbon arc and subsequently to a packed column containing metallic packing media. In all of these designs, a charge is introduced to the particle so that it may be collected using electrostatic forces rather than inertial forces, which have little or no influence on the submicron species.

1.5 ABSORBER CALCULATIONS

1.5.1 Introduction

This brief discussion relative to absorber scrubbers is presented for the sake of completeness. The major portion will concern an example flue gas desulfurization system SO_2 absorber. Absorption is a mass transfer process

and consists of transferring the pollutant gas from the gas stream into the liquid stream. The rate of mass transfer is dependent on liquid-gas interface area, the differences in concentration in the two phases (driving force) and the chemical species present (resolved as a mass transfer coefficient). Most of these data are provided by tables and figures.

1.5.2 Pressure Drop

It has been noted that surface area is directly related to the absorption of a gas. Table 1.7 lists various absorber tower packings by surface area and corresponding pressure drop per foot of packing. Pressure drop in both packed and spray towers would depend on the amount of absorbing liquid passing down the tower, but these values consider normal rates at about 80% of flooding.

1.5.3 FGD Absorption Example

Figure 1.16 shows a schematic SO_2 absorption system. It lists process conditions and physical properties for 90% SO_2 removal using sodium hydroxide (NaOH). The boiler flue gas has been quenched to 120°F as we receive it into the absorber, and the absorber packing is Munters type 12060.

Using the procedures of Section 1.3.1, the 500,000-acfm gas volumetric flow rate can be converted to a mass rate of $1.95 \times 10^6 \text{ lb/hr}$ (air at a molecular weight of 28.9 lb/mol is assumed). The liquid flow rate is

$$\left(\frac{15 \text{ gal}}{1000 \text{ acf}}\right)(500,000 \text{ acfm})\left(\frac{60 \text{ min}}{\text{hr}}\right)(8.34 \text{ lb/gal}) = 3.75 \times 10^6 \text{ lb/hr}$$

The flooding mass velocity is determined using Figure 1.17 by

$$x = \frac{L_M}{G_M} \sqrt{\frac{Q_G}{Q_L - Q_G}} = \frac{3.75 \times 10^6}{1.95 \times 10^6} \sqrt{\frac{0.065 \text{ lb/ft}^3}{62.4 - 0.065}} = 0.062$$

Then from the figure, $y = 0.102$. Flooding mass velocity, G_F , then is

$$G_F = \sqrt{\frac{32.2yQ_GQ_L}{F\mu_L^{0.2}}}$$

where F is the packing factor from Table 1.8.

TABLE 1.7. Comparison of Pressure Drop and Contact Area for Countercurrent Absorber Packing (Gas—2250 lb/(hr ft²); 500 fpm Velocity; Liquid—2000 lb/(hr ft²); 4 gpm/ft²).

Packing Material	Available Surface Area, ft ² /ft ³	Pressure Drop in, w.c. per ft of Packing
Munters 12060	68	0.13
1-in. Koch Flexirings	65	0.90
1-in. Glitsch Ballast Saddles	65	0.80
1-in. Glitsch Ballast Rings	65	1.30
1-in. Intalox Saddles	63	0.75
1-in. Norton Pall Rings	63	0.90
1-in. Celcoat Tellerette	55	0.65
2-in. Maspak FN-200	43	0.75
1-1/2-in. Rashig Rings	40	1.60
1-1/2-in. Glitsch Ballast Rings	40	0.84
1-1/2-in. Koch Flexirings	40	0.75
1-1/2-in. Norton Pall Ring	39	0.75
2-1/2-in. Protak P-251	39	1.00
2-in. Celcoat Tellerette	38	0.30
2-in. Koch Flexirings	35	0.45
2-in. Protak P-252	34	0.82
2-in. Croll Reynolds Spiral-Pak	34	0.24
2-in. Glitsch Ballast Saddles	34	0.55
2-in. Intalox Saddles	33	0.50
2-in. Glitsch Ballast Rings	32	0.55
2-in. Norton Pall Rings	31	0.45
2-in. Heilex 200	30	0.45
3-in. Tellerettes	30	0.24
2-in. Rashig Rings	30	1.40
3-1/2-in. Koch Flexirings	28	0.22
3-in. Glitsch Ballast Saddles	28	0.32
3-in. Intalox Saddles	27	0.30
3-1/2-in. Norton Pall Rings	26	0.22
3-1/2-in. Glitsch Ballast Rings	26	0.22
3-3/4-in. Maspak FN-90	25	0.36
3-in. Heilex 300	23	0.27

TABLE 1.8. Packing Characteristics.

Packing Material	Packing Factor, F , ft ² /ft ³	Mass Transfer Diameter, D_M , in.	Surface Area, a , ft ² /ft ³
Munters 6560	58.8	0.224	123
Munters 12060	27.4	0.400	68
1-in. Rashig Rings	155	1.00	40
1-in. Intalox Saddles	98	1.00	63

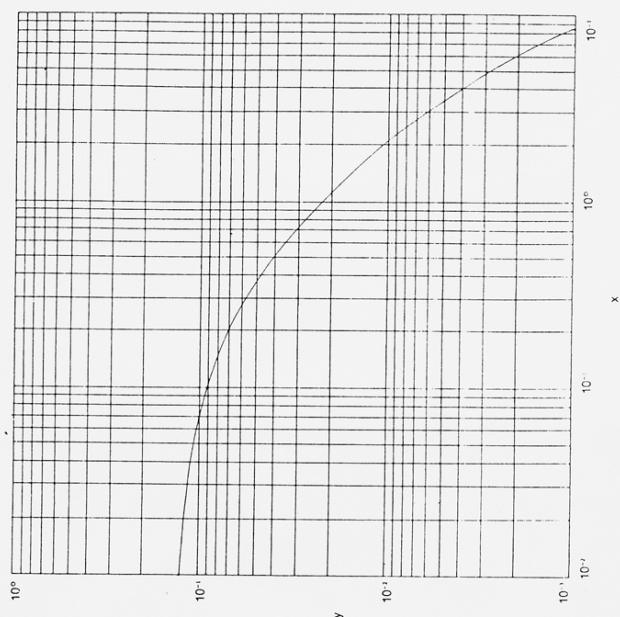


FIGURE 1.17. Flooding velocity graph.

Thus,

$$G_r = \sqrt{\frac{(32.2)(0.102)(0.065)(62.4)}{27.4(1)^{0.2}}} = 0.70 \text{ lb/(sec ft}^2\text{)}$$

Actual tower diameter is estimated at 80% of flooding velocity:

$$\text{area} = \frac{1.95 \times 10^6 \text{ lb/hr}}{(3600 \text{ sec/hr})(0.8)(0.70 \text{ lb/sec ft}^2)} = 967 \text{ ft}^2$$

$$\text{diameter} = \sqrt{\frac{4 \times \text{area}}{\pi}} \approx 35 \text{ ft}$$

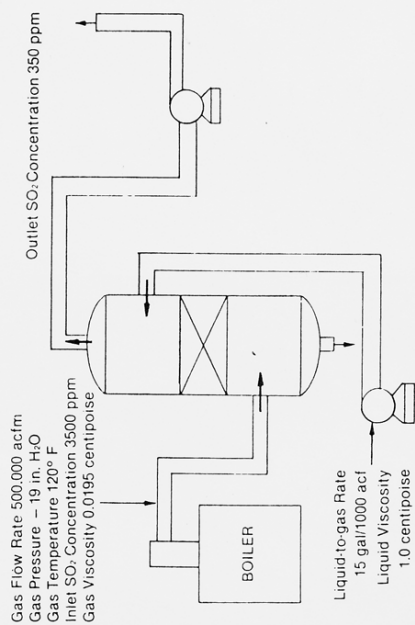


FIGURE 1.16. Sulfur dioxide absorption example schematic.

Pressure drop, from Table 1.7, is 0.13 in. water per ft of packing. Height of packing is found using Figure 1.18 and mass transfer diameter, D_M , from Table 1.8:

$$G'_M = \frac{1.95 \times 10^6 \text{ lb/hr}}{967 \text{ ft}^2} = 2017 \text{ lb/(hr ft}^2\text{)}$$

$$L'_M = \frac{3.75 \times 10^6 \text{ lb/hr}}{967 \text{ ft}^2} = 3878 \text{ lb/(hr ft}^2\text{)}$$

$$Re_G = \frac{D_M G'_M}{\mu_G} = \frac{\left(\frac{0.4}{12}\right)(2017)}{(0.0195)(2.42)} = 1425$$

$$Re_L = \frac{D_M G'_M}{\mu_L} = \frac{\left(\frac{0.4}{12}\right)(3878)}{(1)(2.42)} = 53.4$$

$$Re_G^{0.67} \times Re_L^{0.23} = 324$$

Thus, from Figure 1.18, $J = 17.5$, where J is the mass transfer coefficient. Solve for the overall mass transfer coefficient, $k_G a$, using:

$$\text{gas constant} = R = 10.73 \text{ psi ft}^3/(\text{lb mol}^\circ\text{R})$$

$$\text{absolute temperature} = T = 120 + 460 = 580^\circ\text{R}$$

$$\text{packing surface area} = a = 68 \text{ ft}^2/\text{ft}^3 \text{ from Table 1.8}$$

Schmidt No. = $Sc = \mu_G/q_G D_{12}$, where D_{12} is SO_2 diffusivity of 0.604 ft^2/hr

$$= \frac{(0.0195)(2.42)}{(0.065)(0.604)} = 1.20$$

Therefore

$$k_G a = \frac{J D_{12} a}{R T D_M} Sc^{-2/3} = \frac{(17.5)(0.604)(68)}{(10.73)(580)(0.4/12)} (1.20)^{-2/3} = 3.07$$

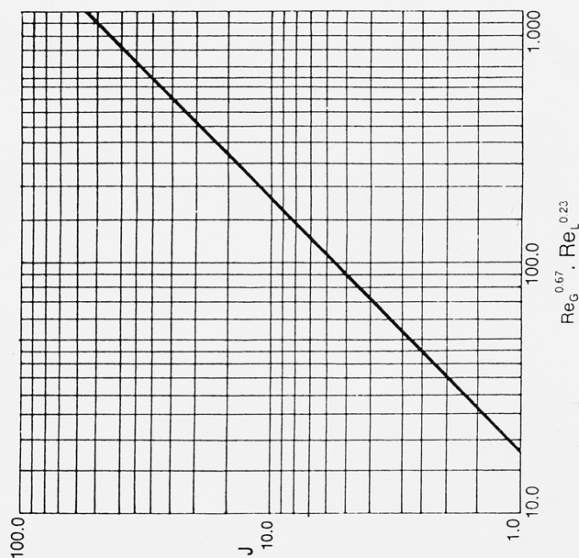


FIGURE 1.18. Mass transfer coefficient graph.

(Note that $k_G a$ will change with gas rate, type packing and other factors.) Packing height, H , then becomes

$$H = \frac{-G'_A}{k_G a M_G P_A} \ln \frac{y_o}{y_i}$$

where

M_G = molecular wt. of gas = 28.9
 P_A = absolute pressure, psia = 14.0
 y_o = SO_2 conc. out, ppm = 350
 y_i = SO_2 conc. in, ppm = 3500

$$H = \frac{-2017}{(3.07)(28.9)(14.0)} \ln \frac{350}{3500} \\ = 3.74 \text{ ft}$$

Total pressure drop is

$$(3.74)(0.13) = 0.5 \text{ in. water}$$

At this point a word of caution should be made that applies to all absorbers: If the gas and/or liquid rates drop below the minimum or exceed the maximum design conditions, the column will fail to operate according to these described theories. For example, Figure 1.19 gives extrapolated theoretical and observed pressure drops for a sieve tray absorber at low gas flow rates. Note that agreement is good from the gas rate of 12.74 lb/sec (design) to 5.7 lb/sec (45% of design, and allowable). Below about 4.7 lb/sec, the pressure drop indicates that the liquid holdup has been lost and the column operation is no longer stable.

1.6 MIST ELIMINATION

1.6.1 Introduction

Mist elimination is an integral part of every wet scrubbing system. A failure at this point may often negate the entire scrubbing process and give rise to the statement that "scrubbers emit more particulates than are in the entering gas stream." It *can* happen, but obviously should not in a properly designed, operated and maintained system.

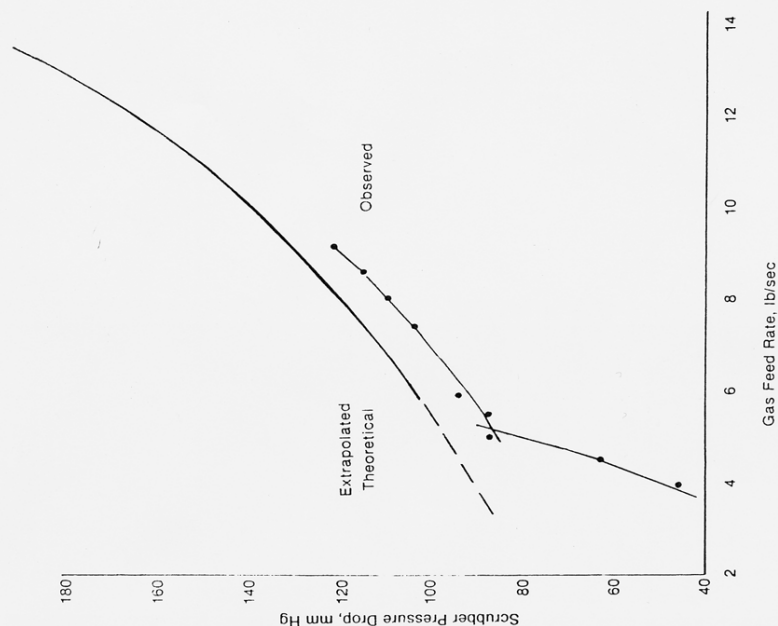


FIGURE 1.19. Theoretical and observed pressure drops in a sieve plate absorber.

Mist eliminators are also called entrainment separators and demisters. They serve to remove the liquid droplets from the exit gas stream whether the droplets are present because of entrainment, reentrainment, condensation or any other mechanism. Effective mist eliminators will remove 99 to 99.9% of the inlet liquid droplets.

1.6.2 Mist Eliminators

Mist eliminators operate mainly by inertial impaction and centrifugal force. However, interception and diffusion may also add to the droplet removal in the inertial impaction devices. The two most common types of inertial impactor mist elimination are the baffles and mesh, and there are numerous configurations of each. The two principal configurations are horizontal gas flow and vertical gas flow. The horizontal gas flow designs, which have recently been introduced into the U.S. from Germany and Japan, permit higher inlet gas velocities and liquid loading. The reason is that the separated liquid droplets do not fall back down into the rising gas if the gas flows horizontally through the eliminators.

Vertical gas flow eliminators usually are of the multipass chevron design such as those shown in Figure 1.20. Two to six passes are common, but three passes are usually sufficient. Of course, these zigzag baffle systems can also be used for horizontal gas flow. Note in Figure 1.20 that the number of passes is counted as the number of baffles in the unit. There is another method of counting passes as the actual turns of the gas stream within the device. In this procedure, the number of passes would be one less than that by the former method. Both systems are encountered in practice.

A modification of the continuous zigzag baffles is the slanted baffle demister shown in Figure 1.21. This improved system for vertical flow gas is inclined 30° from the horizontal and can operate at higher inlet velocities and liquid loadings. Another variation in vertical gas eliminators is the Munters Corporation Euroform® series eliminator shown in Figure 1.22. The walls contain chevron-shaped airfoils which serve to direct the liquid toward the ends of sections. The collected liquid droplets streaming from the edges of each section have less tendency to be reentrained by the rising

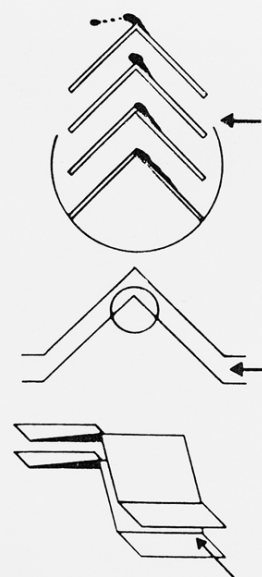


FIGURE 1.20. Chevron mist eliminator designs.

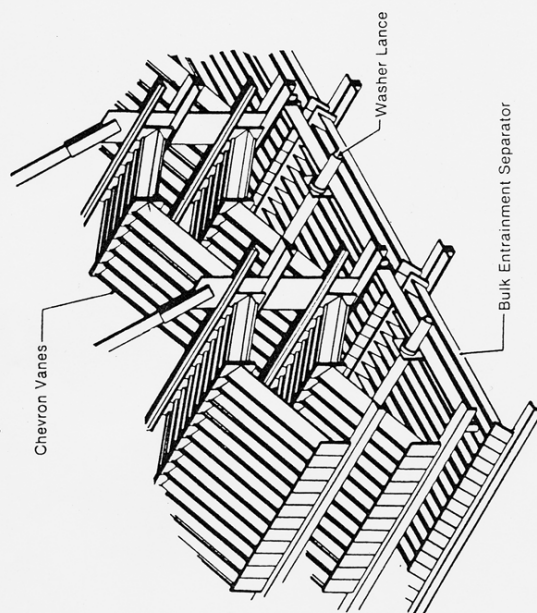


FIGURE 1.21. Slanted zigzag baffle demister (courtesy Munters Corporation).

gas. This T271 eliminator is a high-efficiency, low liquid loading unit which often requires one of the nonlogging chevron mist eliminators, such as that in Figure 1.20, to be positioned below it.

Horizontal gas flow eliminators often include liquid phase separation chambers as shown in Figure 1.23. This reduces the carry-through of collected water.

Mesh-type eliminators are used for vertical gas flow when the gases contain no sticky materials that would plug the mesh. Figure 1.24 shows a typical mesh eliminator. Mesh thickness ranges from 4 to 12 in., with 6 in. being typical. The mesh pads may be installed at from 0 to 45° from the horizontal. Cylindrical mesh fiber packs and packed beds of fibers are also available, but they are less common for industrial scrubbers.

Cyclonic separators are good first-stage mist elimination devices. Coupled with gravitational force, these can remove large droplets. They require more space than the inertial impactors and they are less efficient in industrial sizes, but are less prone to pluggage. Figure 1.9 is a sketch of a cyclonic separator.

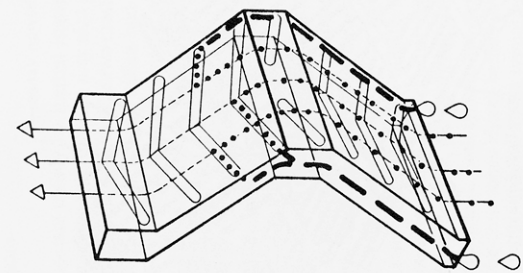


FIGURE 1.22. Munters Corporation Euroform Series T271 mist eliminator.

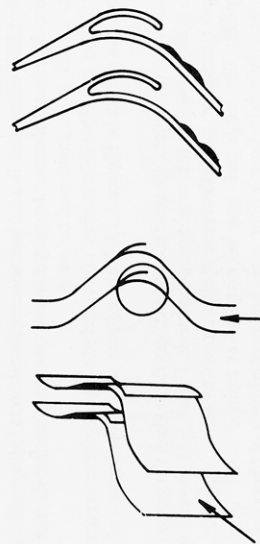
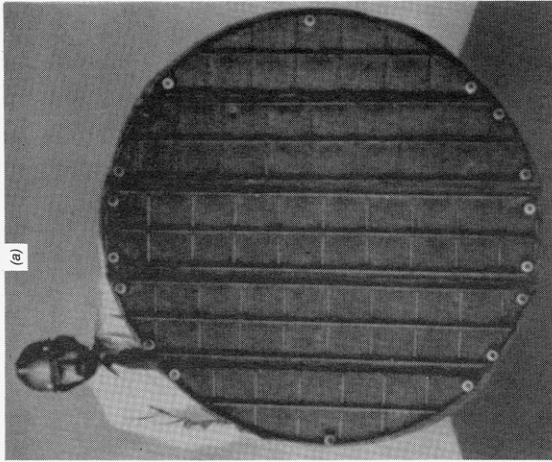


FIGURE 1.23. Phase separation chamber mist eliminator.



(b)

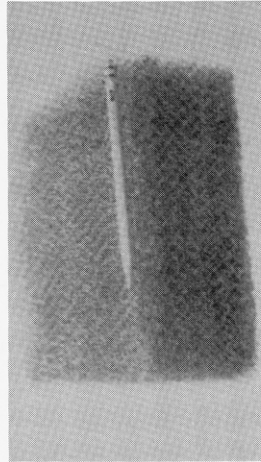


FIGURE 1.24. (a) Typical mesh pad mist eliminator with supports; (b) stainless steel wire mesh section (6 in. thickness).

1.6.3 Design Notes

Impaction-type mist eliminators should have wash provisions to keep them clean and to remove buildup. The wash usually is in the form of a fresh water spray directed from the underside or gas entrance side. The spray nozzles should operate at no greater than 25 psig to reduce the amount of fine droplets that could escape through the eliminator. Typical wash rate is 3 gpm per ft² of surface area.

Inertial impaction baffle or mesh eliminators should be securely tied or fixed in place so they do not move during startup or operation. Material of construction can be quite varied, although lightweight plastic and fiberglass (FRP) usually are advantageous. (FRP is good to 400°F.) Stainless steels and other suitable metals are also commonly used.

1.6.4 Velocities

Velocities in general are capable of ranging from a maximum of 110% of design to a minimum of 60% of design. Efficiencies will decrease as velocities change in either direction. Reported velocities for well designed eliminators are given in Table 1.9.

Chevron mist eliminators with vertical gas flow have 99% and greater effectiveness for F_1 factors of 1.2 to 3.6. The F_1 factor is

$$F_1 = V_G(q_G)^{0.5}$$

where

V_G = superficial gas velocity, ft/sec

q_G = gas density, lb/ft³

For horizontal gas flow, the F_1 ranges from 1.2 to 4.8.

TABLE 1.9. Reported Mist Eliminator Velocities.

Eliminator Type	Gas Flow	Gas Velocity, ft/sec
Zigzag	Horizontal	15-20 (inlet)
Zigzag	Vertical	12-15
Zigzag (30° from horiz.)	Horizontal	16-22
Cyclonic	All	100-130 (inlet)
Mesh	Horizontal	15-23
Mesh	Vertical	10-15
Tube Bank	Horizontal	18-23
Tube Bank	Vertical	12-16
Euroform T271	Vertical	10-20

Maximum velocity in mesh eliminators with vertical gas flow can be estimated in ft/sec by a Stokes' relationship and the Souders-Brown equation:

$$V_{\max} = K \frac{\rho_L - \rho_G}{\rho_G}$$

where

ρ_L = liquid density, lb/ft³

K = 0.35 for mesh density of 9-12 lb/ft³

= 0.40 for <9 lb/ft³

= 0.30 for plastic and Teflon® mesh

If the mesh is installed at some angle, θ , to the horizontal, replace K in the Souders-Brown equation with K_a , where

$$K_a = K + 0.3 \sin \theta$$

Table 1.10 is a comparison chart showing densities of various wire mesh eliminators.

1.6.5 Pressure Drop

Pressure drop in mist eliminators is low, ranging from about 0.5 to 1.0 in. w.c. under normal conditions and 0.2 to 1.5 under extremes. Calculation of pressure drop is quite messy and it is usually sufficient to know the maximum pressure drop, ΔP_M , at the maximum allowable velocity, V_M . Then pressure drop can be estimated for any actual velocity, V_a , by

$$\Delta P = \Delta P_M \left(\frac{V_a}{V_M} \right)^2$$

1.7 ADDITIONAL SUGGESTED READING

Given that there are nearly 500 air pollution control companies in existence in the United States, new developments occur frequently. Many of these developments are more claim than substance; therefore, those people interested in the application of wet scrubbers need to keep abreast of the technical literature being offered, rather than the sales literature.

*Registered trademark of E. I. du Pont de Nemours and Company, Wilmington, DE.

sodium, magnesium and other metals which might exist in the fuel as organometallic compounds. One does not believe the particle size analysis until a thorough investigation of the fuel is carried out. Burning a high vanadium content No. 6 oil can add 3–6 in. w.c. to a venturi pressure drop. A projection should be made of alternative fuel sources which may, in the future, be used so that the scrubber and fan may be adequately sized.

Item (3) is important because high chloride or dissolved salt quantities in makeup water can destroy even stainless steel scrubbers. In boiler scrubbing systems, the chemical mix is an unsavory one. Acidic sulfur and chloride species are typically mixed with sodium or calcium alkalis at elevated temperatures—a perfect environment for stress corrosion cracking and pitting. Also, the introduction of sodium-containing makeup water at the inlet (high-temperature) zone of the scrubber may promote spray drying of these compounds, creating a submicron fume. In many instances it is better to mix decanted water from the flue gas desulfurization (FGD) system than to use fresh water.

Item (4) is required to determine the corrected outlet loading when the flue gases are adjusted for CO₂ content. Most codes stipulate 12% CO₂ correction. Therefore, systems whose average flue gas CO₂ is lower will require lower outlet loadings. Thus it is imperative to have good burner control for maximization of combustion performance and CO₂ loadings.

Item (5), boiler shutdown requirement, sets the range of operation of the scrubber. One must know if the flue CO₂ loading will also change on shutdown so that pressure drops can be calculated for lowest and highest combustion rate. Also, the intended duty (base loaded, peaking, swing) of the boiler must be known. Automatic draft controls derive their engineering inputs from the intended duty. Drain back provisions on peaking or swing duty boilers are important, determining freeboard requirements of recirculation tanks and holdup facilities, as well as liquid seals.

Item (6), the type of fuel combustor, is obviously important. High-turbulence pulverized coal burners create excellent heat release and very fine particulate. Stoker-fired boilers tend to run at higher excess air levels, yet have somewhat reduced particle loadings. These data help put the given particle size analysis in perspective. Unduly high amounts of submicron particulate from stoker-fired boilers would draw attention to the particular fuel used during the test. Sometimes adjustments can more readily be made in the fuel source than in the cleanup equipment.

Items (7) and (8) help the designer select the proper scrubber to suit the plant's physical constraints. He may wish to scrub particulate in one vessel and use an entirely different vessel for SO₂ control. He may be forced to combine them into one unit. He may be able to place his waste handling system directly under the scrubber, or be forced to pump it to another facility. The breeching may be simply connected to the scrubber or require exten-

sive modifications. The scrubber stack may leave the building in the lee of a taller stack—a poor arrangement for discharge of saturated gases. Or, it may be able to enter the existing stack, saving complexity and money. The site places important constraints on all systems designs, even where a new facility is being contemplated starting from the ground up. The surrounding area is important in selecting the required stack height for proper dispersion.

3.8.2 Gas Absorption

The absorption of SO₂ is the predominant function of absorbers applied to industrial boilers. There exist a variety of gas absorbers available to the applications engineer, deriving their use from the type of sludge disposal system to be used. These sludge systems are separated into two categories:

- (1) *Recoverable or regenerable*: the absorbed SO₂ is chemically treated so that a reusable, if not resalable, product is created. Some products are gypsum for use in wallboard, elemental sulfur, sulfuric acid and sulfur dioxide.

- (2) *Throwaway*: these would be better described as "storage" systems since the by-products must be further handled, perhaps once when produced (in the case of a settling pond) and years later when the storage area must be enlarged or excavated. These waste products have little or no market value. The most prevalent throwaway material is calcium sulfate.

These systems may be cyclic in the absorption circuit yet be batch in the sludge handling circuit. The gas absorber becomes a minor part of the entire system, and the wet chemistry becomes most important.

Several commercially available regenerative FGD systems are listed in Table 3.10. Generally speaking, regenerative systems require thorough particulate separation from the gas stream. These systems utilize closed-loop

TABLE 3.10. Regenerative FGD Systems.

Process	Reagent, Primary	Product
Double alkali (dual alkali)	Sodium hydroxide	Calcium sulfate (caustic returned)
Dilute sulfuric acid	Sulfuric acid	Calcium sulfate (acid returned)
Wellman-Lord	Sodium sulfite	SO ₂
Magnesium oxide	Magnesium oxide	SO ₂
Citrate	Sodium citrate	Sulfur

venturi scrubbers as particulate collectors or precipitators or baghouses. Required efficiencies are over 98% in many cases. Even small amounts of abrasive particulate can cause operational problems in the regeneration system. Venturi scrubbers must be 6–15 in. w.c. on coal-fired boilers for proper removal efficiency.

Retained fly ash will build up in regenerative flue gas desulfurization systems, reducing the operating life of the system itself and detracting from the product quality. Many pilot FGD systems of a regenerative nature perform well, only to have full-scale systems become operational nightmares. Large pilot facilities (10% or more of expected flue gas volume) are suggested.

Absorbers for regenerative systems can have smaller openings than their counterparts experiencing a larger mass flow of particulate. These gas absorbers may be tray towers, spray towers, bubble cap tray towers, packed towers or other devices described earlier. These absorbers, in general, operate with dilute scrubbing liquids since the end products desired have, in many instances, their own vapor pressure effects. Concentrated solutions may evolve other contaminants through a stripping action. Many systems start with sodium carbonate, sodium hydroxide or other soluble alkali which acts as a carrier of the sulfate or sulfite radical for further liquid-phase chemical operations. Thus, the absorber circuit may be cyclical, containing its own recirculation and makeup alkali system, while the regeneration stage may be batch. Extensive texts are available on the chemistry of these various systems for reader reference.

The absorber of preference is a spray tower or similar device wherein the vessel exposes the greatest surface area per unit volume to the gas stream. Devices with weirs, caps, baffles, etc., are, though effective, not as desirable given their higher pressure drops and internal complexity. Liquid-to-gas ratios (L/G) are high (e.g., 25–100 gal/1000 acfm) given the low concentrations of reagents. Many reactions are slow in execution and therefore require retention tanks. When this is the case, the absorber should discharge directly into the retention tank, or by the shortest path. Horizontal runs are avoided, even when soluble alkali is used, so as to reduce scale deposition or settling of residual fly ash. Pumps should be avoided between the absorber and the retention tank because they can present operational problems in both devices.

Retention tanks should accommodate the possibility of settling of solids, should provide for agitation and blow-back. Tanks should be fully drainable, if possible, and not designed only for pump-out. Instrumentation, such as pH probes, should be protected by stilling wells that are exposed to constant agitation. These probes must be fully accessible and, obviously, spares should be stocked. Tanks mounted indoors will evaporate contaminant and reagent along with steam; therefore covered, vented tanks are sug-

gested. These covers should be fully removable, if possible, for worker access. Rubber-lined tanks should include shop-installed welding clips, reducing the chance of accidental welding onto the surface of previously lined vessels. Linings should be checked for thickness upon installation at a spot which is accessible for future checks to determine lining wear or degradation. Heat tracing, if used, should be externally available to the operating engineer.

Since the absorbing liquid typically returns from processes wherein heat is lost, the absorber typically condenses water vapor (especially if installed after a wet scrubber for particulate removal), causing a net increase in water vapor to the absorber circuit. This dilutes the reagent, and must be compensated for in the circuit water balance. Many times this forces a bleed of some valuable alkali from the absorber so as to physically maintain water levels. When this bleed cannot be utilized as shower water, reagent dilution or mix water, design scopes must include some means of water treatment for this flow. One method involves sending excess water to the particulate removal circuit as makeup. If this flow contains soluble alkali, one must anticipate the effects on the presence of dissolved salts in the fly ash disposal system. This water buildup can be equally important if a dry primary collector is used, especially where counterflow absorbers are used (the coolest scrubbing liquid sees gases last). The evaporation rate is reduced from the theoretical amount unless the balance includes the condensation of water vapor in the absorber.

Throwaway systems are easier to design if one neglects the ultimate disposal of the waste liquor or sludge. Many times, the sludge may be disposed of in landfills or ponds, prompting an engineering decision relating more to materials handling and less to chemistry.

The ultimate disposal of the sludge determines the design of the scrubbing system. Soluble alkali systems which absorb SO_2 using sodium hydroxide or sodium carbonate are well suited to systems where the resulting sodium sulfite and sulfate can be reused, such as in the kraft pulping industry. These scrubbers are simple in design, using a low- (6–12 in.) energy venturi scrubber with adjustable throat followed by a tray absorber or packed tower. Some units do not even use the absorber for 80% SO_2 removal, given the high activity of caustic on SO_2 . These units operate on combined-loop recirculation systems with makeup to the venturi sump for caustic and fresh water makeup to the venturi headers to control evaporative losses. Figure 3.18, from Dow Chemical [3], shows the effects of recycle pH on SO_2 absorption.

Fly ash is settled out and the supernatant liquor returned to process. This is also the first stage of the dual alkali system. In the dual alkali system, this liquid flow is then slaked with lime to create calcium sulfate solids and a caustic supernatant which is returned to the first stage. Thus it is a throw-

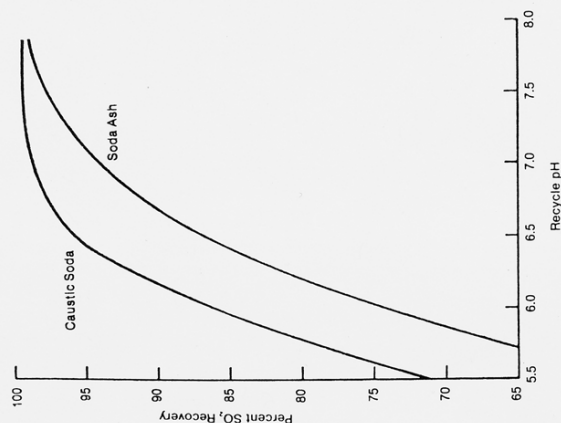


FIGURE 3.18. Sulfur dioxide recovery vs. recycle pH (source: Dow Chemical USA (3)).

away system (calcium sulfate to landfill) and a regenerative system (caustic returned to the scrubber) in one. Unfortunately, cross migration of insoluble compounds can occur, yielding operational problems in the scrubber (scale, erosion, etc.). Once again, condensation in the absorber can occur, requiring a liquid balance for each particular device. To avoid spray drying of caustic at the inlet of the venturi, makeup water alone should be introduced into the hot sections of the venturi with returned caustic entering once the gas temperature is below 400°F. Level controls in the absorber prompt increases in liquor additions to the venturi circuit. This feedback control is a common remedy for liquid level "hunting" in dual stage scrubbers. One uses the sensor in the least fluctuating device (usually the absorber since it is downstream from areas of evaporation and high carryover) feeding back to control valves on the most sensitive device (usually the scrubber). This applies to level control, pH and conductivity measurements.

3.8.3 Scrubbing System Components

Throwaway lime or limestone systems have five major areas, each requiring a mass balance:

- (1) Slurry preparation
- (2) Absorber
- (3) Recycle/retention tank
- (4) Wash tank
- (5) Waste disposal

Lime or limestone is thoroughly mixed with water and recycled supernatant from the system's waste disposal process. Agitators blend this slurry to a weight solids content of 15%. Rubber-line centrifugal pumps distribute this slurry on a continuous flow loop to the absorber, a valve actuated by pH instrumentation controlling slurry addition, and a density system controlling dilution.

The absorber may be a tray tower, but the most prevalent design is an open spray tower. These devices rely on a spray of hydraulically atomized scrubbing liquid to provide the surface area necessary for gas-to-liquid exchange. Prehumidification sprays are sometimes used, incorporating water, to create sulfurous acid when then reacts quickly with the alkali spray. If insufficient alkali is present, the reaction can produce hard and soft scale deposits. Therefore, the scrubbing liquid balance must avoid saturating the liquid in any zone of the absorber. This is accomplished by returning supernatant from the clarification step of the waste disposal system and adding makeup water to the chevron droplet eliminator or wash tank. There is always alkali available for reaction with SO_2 .

The absorber is typically a vertical or horizontal chamber with spray headers. Sometimes target devices are used to increase turbulence in the absorber. Some typical design details for various components of an absorber are listed in Table 3.11.

The recycle system is one of the most important parts of the lime/limestone absorption system. It is estimated that chemical reactions to sulfate may take up to 10 min to go to completion. This requires adequate holdup to avoid sending partially reacted scrubbing liquid back to the absorber where it may scale. Thus, the agitated recycle tanks can contain up to 10 min retention time, sometimes many thousands of gallons. This is prompted by the high L/G , which in turn is prompted by the need to create absorption surface area via hydraulic forces. It is known that the greatest surface area per unit volume exists a short distance from a spray nozzle, decreasing from there out from the nozzle. New devices, such as the Catenary Grid Scrubber® (patented), Figure 3.19, use grids of widely spaced wire to act as

TABLE 3.11. SO₂ Absorber Application Guide.

Specify: Spray tower vertical velocity, 8–10 ft/sec			
Header velocities, 6–8 ft/sec			
Chevron mist eliminators face velocity, 550 ft/min based on open area (800 ft/min max.)			
Pressure drop, 0.5–1.5 in. w.c.			
Chemical and Liquid Requirements (for limestone scrubber):			
Emission Rate	Mol Limestone/Mol SO ₂	Required L/G, gal/1000 acf	
1.5 lb SO ₂ /10 ⁶ Btu	0.65–0.75	Saturated Gal	50
1.0 lb SO ₂ /10 ⁶ Btu	0.75–0.8		80
0.5 lb SO ₂ /10 ⁶ Btu	0.9–0.95		90

targets for rebreaking of the scrubbing liquid. This increases the aggregate surface area of the scrubbing liquid, and increases absorption per unit volume without using higher header pressures or other less efficient atomization techniques.

Waste handling systems include dewatering systems (vacuum filters, clarifiers or combined device systems), holdup tanks, and decant water return. This decanted or filtered water, commonly called supernatant, is returned for reuse as shower water or makeup water. A holdup tank is required since its flow can be discontinuous. It also assists in starting up the system, permitting the waste disposal system to operate without the absorber circuitry in operation.

Sometimes the waste is sent to settling ponds. This mixture of dissolved solids (low quantities of chlorinated metalics), suspended solids (calcium sulfate and sulfite), and water is sometimes blended with the fly ash recovered from the particulate removal device. Adequate facilities must be made for this discharge. Therein lies the argument against throwaway systems. The expense and complexity of the solids disposal system must be investigated as a significant portion of the investment.

Soluble alkali systems, those using sodium hydroxide or sodium carbonate or other similar alkalis, are throwaway systems of “first the good news, then the bad news” type. The good news is that the use of a soluble alkali reduces the effects of scaling on the scrubber absorption surfaces. This improves the on-stream reliability of the system and reduces off-line maintenance expenses. The bad news is that the waste liquor contains a mixture of sodium bisulfite and sulfate, along with (especially in coal burning applications where the fuel contains chlorides) residual halogens. Typical chemical composition of such a system blowdown as a function of pH is given in

Figure 3.20. These items are leachable into groundwater, requiring further treatment prior to disposal. Hence, we have the dual alkali systems wherein a soluble alkali absorber is mated with a water treatment system that typically slakes the soluble waste stream with lime or limestone, creating an insoluble waste product. This operation requires exacting attention to the wash circuitry in the waste treatment area. Obviously, excessive water consumption in an attempt to thoroughly reduce the leachable salts in the waste slurry is undesirable. In general, a double alkali system requires greater

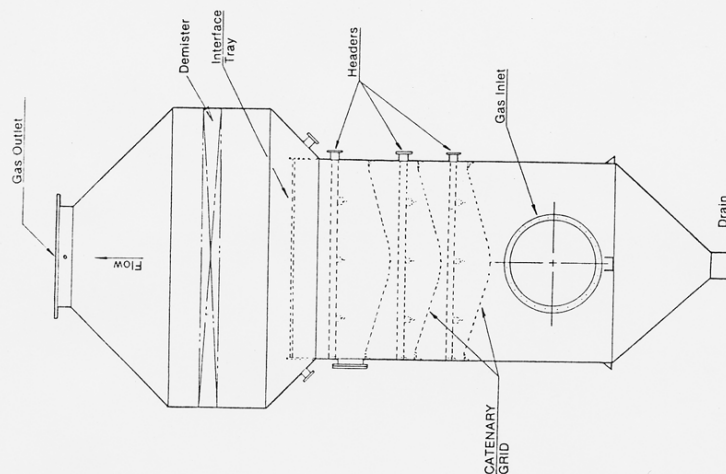


FIGURE 3.19. Catenary Grid Absorber® (patented).

spray dry caustic. It should be permitted to mix and react with the absorbed SO_2 in the sump, and be further mixed by the recirculation pump before being sent to the absorber media. Makeup water should be directed at the bottom of the mist eliminator device or at the entry to the scrubber, serving to cool and saturate the gases. The scrubbing liquor should be controlled by a pH controller mounted in the pump discharge bypass or in a stilling well in the scrubber sump so that it measures the internal loop (not the bleed) pH. A worthwhile addition is a sample tap in the recycle line to take samples for sulfite/bisulfite analysis. Tables 3.13 and 3.14 show the basic chemistry of the absorption of sulfur dioxide and its conversion to salts when using lime, limestone, sodium hydroxide, and sodium carbonate. These reactions are based upon a stoichiometry of 1.0; therefore, in actual operating systems chemical reagents in excess of these figures may be needed. As mentioned previously, designers balance the removal efficiency requirements versus operating constraints (such as the propensity of the scrubbing liquid to produce scale that may plug the absorption device) in selecting the proper operating point. These tables will provide the reader with guidelines, however, as to the approximate chemical consumption for these reagents.

3.9 ODOR CONTROL SCRUBBERS

3.9.1 Introduction

Odors consist of particles that are odorous or contain adsorbed odors and/or odorous gases. Scrubbers are capable of removing both gases and particles, and can be useful for odor control. Table 3.15 shows a crude listing of various dry odor control techniques and the approximate times required for 90% reduction of the odor. This is expressed as odor units (o.u.). Time for wet scrubbing odor control includes time for diffusion and absorption plus chemical reaction.

TABLE 3.12. Sodium-Based Absorption Application Guide.

Parameter	Value	90	94	96
SO_2 removal, % efficiency		0.85-1.0	0.9-1.0	1.0-1.1
Recycle:				
lb NaOH/lb SO_2		1.85-2.2	2.1-2.4	2.2-2.6
lb Na_2CO_3 /lb SO_2		6.5-6.8	6.8-7.0	7.0-7.2
pH (internal loop)		0.5	0.6-0.7	1.0
Mol sulfite/bisulfite		1.5	2.0	2.5
Absorber, number of theoretical trays		10	10	10
Tray tower (L/G), gal/1000 acf saturated gas				

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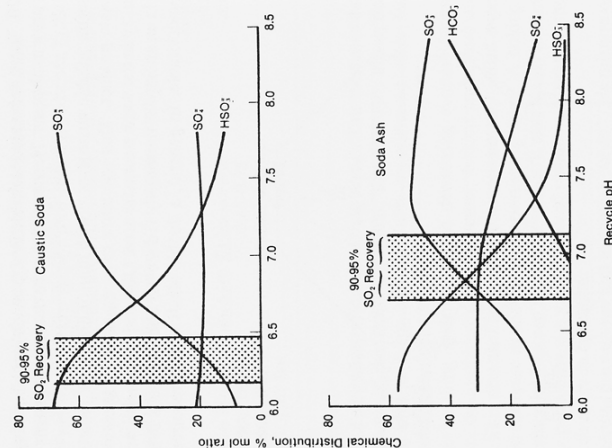
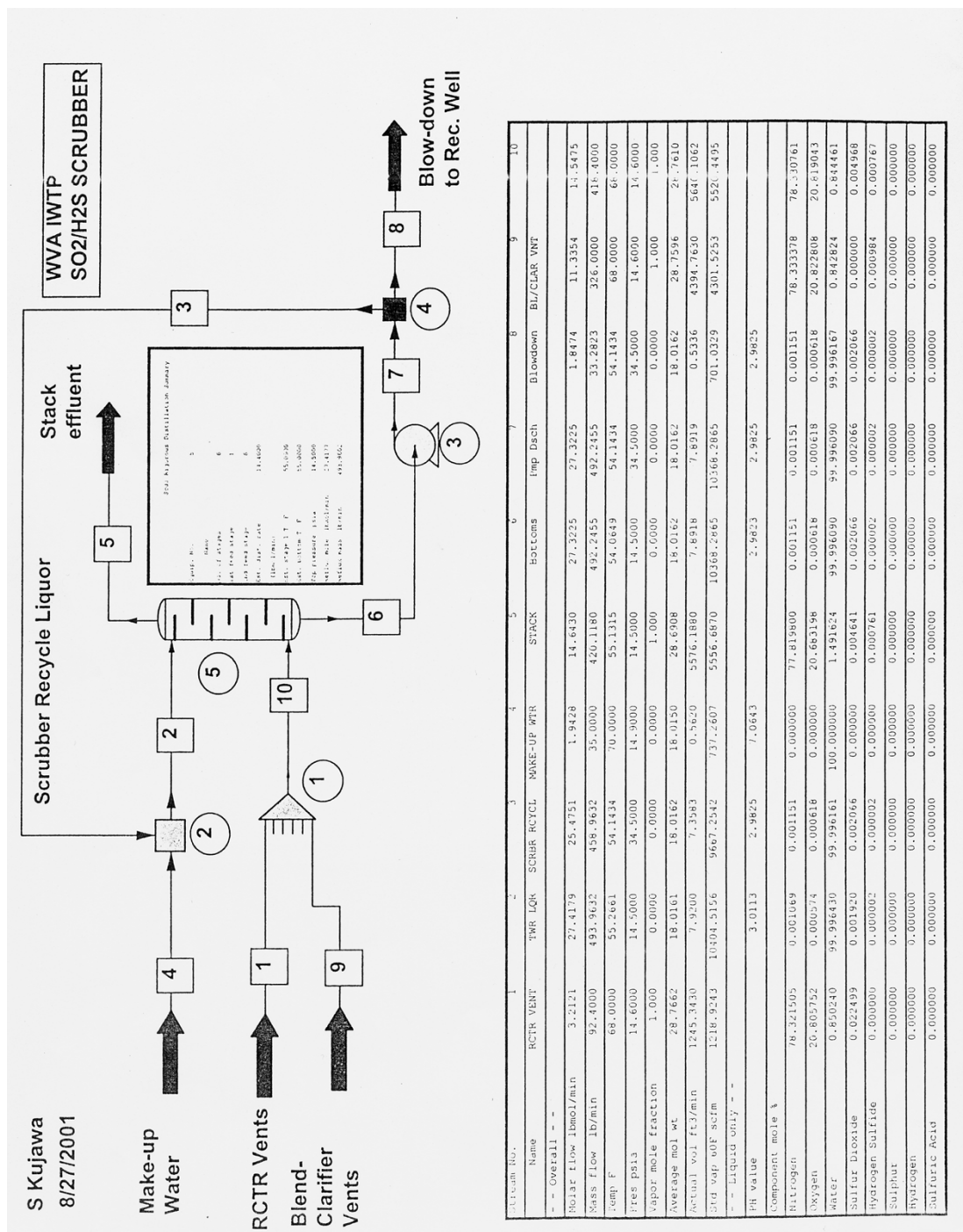


FIGURE 3.20. Blowdown composition vs. pH (source: Dow Chemical USA [3]).

wash flow rates to achieve the same waste sludge conditions as a direct lime/limestone system. With the scaling problems overcome in lime/limestone systems, given better internal loop chemistry, these systems are generally preferred over soluble alkali systems unless the waste liquor can be used in the process directly without further treatment.

Given the higher reactivity of the soluble alkali systems, the absorbers are simpler. One finds tray towers, spray towers, bubblecap trays, wetted chevrons, packed towers, air washers and low-energy venturi scrubbers all performing well on this application, as shown in Table 3.12. Note the much lower L/G requirement than the limestone values in Table 3.11.

Caustic is premixed with water and then fed into the absorber sump. The caustic should not be fed to the inlet of the scrubber unless one wishes to



Appendix C: Equipment Data Sheet

[illegible]

○ CIRCLED NUMBERS TO BE COMPLETED BY REQUESTER

Suggested Sources for Scrubber

1. CAMTEC Industrial Sales
P.O. Box 1700
Sandy, UT 84091
(801) 566-6000
Doug Campbell
2. Rocky Mountain Process Group
872 Don Cubero Avenue
Santa Fe, NM 87501
(505) 983-1661
3. Process Combustion Corporation
5460 Horning Road
Pittsburgh, PA 15236
(412) 655-0955
Ralph Koenig

Date:
Revision:
By:

IWTP SO₂ SCRUBBER DATA SHEET

DESIGN REQUIREMENTS:

Type - The IWTP SO₂ Scrubber shall be a vertical packed tower type unit, designed for continuous service, capable of being mounted on grating or a concrete pad.

Operating Conditions - The Industrial Wastewater Treatment Plant (IWTP) has a tank ventilation system (hoods, ducting and fans) that exhaust vapors from a variety of process tanks, including: blending tanks, sludge tanks, oil batch tanks and clarifiers. The vapors are acidic. The scrubber will be located outdoors and will primarily absorb Sulfur Dioxide (SO₂) from the ventilation air. The scrubbed air will then be discharged to atmosphere. Caustic (Sodium Hydroxide) solution will most likely be used for the scrubber liquid. The design parameters for the scrubber are:

Inlet Temperature	85 °F
Inlet Pressure	14.4 psia (local atmos. pressure is 14.5 psia)
Inlet Flow rate	418 Lb/min (5,640 ACFM)
Inlet Molecular Weight	28.6
Inlet Density	.074 Lb/cu.ft. @ 68 °F
Inlet SO ₂ concentration	75 ppmv
Inlet Hydrogen Sulfide (H ₂ S) concentration	10 ppmv
Inlet Water (H ₂ O) vapor concentration	3.5%
Inlet required scrubber liquid pH	vendor to specify
Inlet required scrubber liquid flow rate	vendor to specify
Scrubber liquid blow down flow rate	vendor to specify
Outlet required SO ₂ concentration	<5 ppmv
Outlet required H ₂ S concentration	<4 ppmv
Outlet Temperature	vendor to specify
Outlet Pressure	1-3 in. w.c. vacuum
Outlet required scrubber liquid pH	8-10

System Components - In general the scrubber system shall include:

1. packed tower scrubber system with spraying header, packing and mist eliminator;
2. scrubber liquid collection sump with ports (for drain and instruments such as level indicators and alarms and pH meters);
3. scrubber liquid recirculating pump/spraying system with filter;
4. PVC or FRP housing with insulation and drain connection;
5. vibration isolation;
6. flanged inlet/outlet connections with ports for instruments (such as differential pressure gauge);
7. access port for maintenance;
8. support frame and base drilled for mounting.

Date:
Revision:
By:

9. induced draft fan;
10. caustic liquid injection system; and
11. scrubber outlet liquid pH controller.

Materials of Construction - The scrubber wetted surfaces shall be PVC or Polypropylene or FRP, compatible with the liquid and vapors. The other components shall be constructed of material that is suitable for an outdoor location. The construction shall include a weather cover for the scrubber liquid pump motor. The vendor shall supply all the equipment required for winter operation, including heat trace and insulation.

Unit Performance - The scrubber shall be capable of reducing the SO₂ and H₂S concentrations in the discharge air flow to the levels specified above. The scrubber liquid system shall be capable of maintaining the pH of the outlet scrubber liquid in the range of 8-10.

Electrical Instruments and Controls - The scrubber liquid pump motor shall operate on 480 volt three phase 60 hertz electrical power. The motor starter shall be provided by the purchaser (MSE).

Equipment warranty :

Any equipment shall be warranted by the manufacturer for a period of not less than one year. The warranty shall cover the materials, workmanship and labor.

Appendix D: Vendor Quote – Rocky Mountain Process Group

Rocky Mountain Process Group

872 Don Cubero Avenue, Santa Fe, New Mexico 87505

January 9, 2002

William T. Ferko
Subcontract Administrator
MSE Technology Applications, Inc.
P. O. Box 4078
200 Technology Way
Butte, MT 59702

SUBJECT: TECHNICAL PROPOSAL FOR MSE-TA Solicitation # 81123G
RMPG Document 10201, Rev. 0

Dear Mr. Ferko:

Rocky Mountain Process Group is pleased to quote the engineering and fabrication of equipment as described in the referenced MSE-TA Technical Proposal, dated January 8, 2002. Attached is a technical description of the equipment and services proposed by RMPG. An RMPG Cost Proposal is being forwarded as a separate document. Hard copies of all electronic documents will also be forwarded to MSE-TA.

RMPG is a partnership that includes as a partner, Mr. Ralph Koenig, the president of the Merlin Co. Merlin's background and experience, including four successful process systems and equipment supplied to MSE-TA over the past several years, are a strong compliment to that of other partners within RMPG.

Partners in RMPG have completed numerous jobs that are similar in scope and application to the proposed IWTP job over the last 10 years. Please refer to our web site, www.rmprocess.com, for details. Much of our work has been in collaboration with the Departments of Energy and Defense.

If there are any questions or comments regarding the following Technical Proposal, please contact me directly at (505) 983-1661. Thank you for this opportunity to work with MSE-TA.

Best regards,

John S. Vavruska
Project Leader and Senior Engineering Specialist

Attachments a/s

Rocky Mountain Process Group

872 Don Cubero Avenue, Santa Fe, New Mexico 87505

COST PROPOSAL IWTP SO₂ SCRUBBER MSE-TA SOLICITATION NO 81123G RMPG Document 10204, Rev. 0

1.0 BACKGROUND

MSE Technology Applications, Inc. (MSE-TA) has been contracted to provide a sulfur dioxide scrubber system for installation into an Industrial Wastewater Treatment Plant (IWTP). The scrubber will remove, by countercurrent gas-liquid contacting and absorption, sulfur dioxide (SO₂) and hydrogen sulfide (H₂S) vapors from an acidic gas tank ventilation air stream.

RMPG proposes to supply all the major components of the SO₂ scrubber system as a single integrated package. The equipment package will include an induced draft fan, packed-bed absorber, a short vent stack, and all associated instrumentation and controls. The proposed equipment for RMPG supply is illustrated in the associated RMPG sketches sent under separate cover.

2.0 QUOTE FOR AN INTEGRATED SO₂ SCRUBBER SYSTEM

RMPG proposes to supply the major components of the SO₂ scrubber system as a single integrated package. By quoting the entire package of major components, we can ensure that each unit matches the next with similar methods of construction, similar instrumentation and controls (same brand and grade), compatible interfacing, and similar appearance. By supplying a single integrated package, RMPG can also provide complete coverage of the supplied equipment with a single performance guarantee and materials warranty.

3.0 HARDWARE COSTS

RMPG proposes to supply the major components of the SO₂ scrubber system as a single integrated package. The base cost for the hardware and supporting engineering services for the equipment listed below is:

\$98,860.00 F.O.B. point or points of shipment.

This proposal is valid for thirty (30) days.

Tel: (505) 983-1661

Fax: (505) 983-8607

E-Mail: info@rmprocess.com

Rocky Mountain Process Group
IWTP SO2 SCRUBBER
MSE-TA RFP #81123G
RMPG Document 10204, Rev 0
January 8, 2002

3.1 PACKED BED SCRUBBER

In accordance with the MSE-TA Request for Proposal, RMPG will supply the following equipment (each is described in the RMPG Technical Proposal):

- Packed bed scrubber tower fabricated of FRP with scrub solution spray distribution nozzle, random packing, mist eliminator, and access port
- Scrubber liquid collection sump integral to packed bed scrubber tower with ports (for drain, level and pH control instrumentation)
- Scrubber liquid recirculation pump with in-line filter
- Scrubber blowdown pH control and reagent metering pump
- Packed bed scrubber instrumentation and control hardware for liquid density (dissolved solids) and sump liquid level control
- Packed bed scrubber with base drilling for mounting
- Induced draft fan
- Caustic liquid injection system
- Short vent stack mounted to top of absorber

The cost of these items is included in the base hardware cost noted in Section 3.0 above.

3.6 INDUCED DRAFT FAN

In accordance with the MSE-TA Request for Proposal, RMPG will supply the following equipment as described in the RMPG Technical Proposal:

- Induced draft fan housing and motor.

The cost of these items is included in the base hardware cost noted in Section 3.0 above.

4.0 DELIVERABLES AND SCHEDULE

RMPG will supply the following data packages.

4.1 FIRST DATA PACKAGE

Assuming receipt of order on 2/1/02, RMPG will deliver the first data package on or before 3/6/02. The package will contain the following as a minimum:

4.1.1 Drawings

- Process Flow Diagram (PFD)
- P&ID
- Plan view
- Elevation view

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- Miscellaneous drawings (anchor bolts plan, interface flanges, etc.)

4.1.2 Equipment List

- Components
- Piping
- Valves
- Instrumentation
- Special Items

4.2 SECOND DATA PACKAGE

RMPG will deliver the second data package on or before 4/11/02. The package will contain the following as a minimum:

4.2.1 Drawings

- Major components
- Mechanical assembly drawings (showing dimensions, fitting sizes, interface points, etc.)
- Electrical one-line drawings

4.2.2 Updated Equipment Lists

- Components
- Piping
- Valves
- Instrumentation
- Special Items
- Recommended spare parts

4.2.3 Calculations

- Mass and energy balance and equipment sizing
- Fluid flow (pressure drops, line sizing, pump sizing, fan sizing, etc.)
- Utility requirements
- Other miscellaneous calculations (may include a cost adjustment if extensive)

4.3 THIRD DATA PACKAGE

RMPG will deliver the third data package on or before 6/4/02. The package will contain the following as a minimum:

4.3.1 Drawings

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- Control logic diagrams
- Electrical and control wiring diagrams

4.3.2 Documentation

- Packaging, lifting, and transportation requirements or related special procedures
- Control description with list of control setpoints and alarm points
- Equipment specification and technical data sheets
- Installation requirements with procedures
- Checkout test procedures
- Maintenance manual with procedures and schedule
- Operations manual with procedures
- Training information
- Updated equipment lists (including recommended spare parts)

4.4 EQUIPMENT DELIVERY

RMPG can deliver the entire lot of equipment and documentation described above as early as five (5) months after receipt of order (approximately 6/30/02), depending on the speed of documentation turnaround. To the extent possible, RMPG will work with MSE-TA to expedite this schedule if an earlier delivery date is required.

5.0 SERVICE AFTER THE SALE

Twenty four hours of RMPG engineering support with communications by telephone, fax, and e-mail (no travel) is included in the base cost.

RMPG will satisfy warranty claims in accordance with the RMPG Standard Conditions of Sale (attached).

RMPG engineers and technicians are available for assistance with equipment startup and operator training in accordance with the terms of the current RMPG Rate Schedule for Engineering Services at the time of the service.

END OF COST PROPOSAL

Rocky Mountain Process Group

872 Don Cubero Avenue, Santa Fe, New Mexico 87505

January 9, 2002

William T. Ferko
Subcontract Administrator
MSE Technology Applications, Inc.
P. O. Box 4078
200 Technology Way
Butte, MT 59702

SUBJECT: COST PROPOSAL FOR MSE-TA Solicitation # 81123G
RMPG Document 10203, Rev. 0

Dear Mr Ferko:

Rocky Mountain Process Group is pleased to quote the engineering, fabrication, and preparation for shipment of equipment as described in the referenced MSE-TA Technical Proposal, dated January 8, 2002. Attached is the cost summary for the equipment and services proposed by RMPG. An RMPG Technical Proposal is being forwarded as a separate document. Hard copies of all electronic documents will also be forwarded to MSE-TA. The completed MSE-TA Solicitation/Contract Order for Commercial Items will be faxed separately.

RMPG has attached a Standard Conditions of Sale for your review.

If you have any questions or comments regarding the Cost or Technical Proposals, please contact me directly at 505-983-1661. Thank you for this opportunity to work with MSE-TA.

Best regards,

John S. Vavruska
Project Leader and Senior Engineering Specialist

Attachments a/s

Tel: (505) 983-1661 Fax: (505) 983-8607 E-Mail: info@rmprocess.com

Appendix E: Vendor Quote – Met-Pro Corporation Duall Division



Duall Division

1550 Industrial Drive, Owosso, MI 48867-9799 • (989) 725-8184 • FAX: (989) 725-8188
E-mail: dualldiv@shlanet.org • Web Site: www.met-pro.com/duall.html

THANK YOU FOR YOUR INQUIRY. WE ARE PLEASED TO SUBMIT THE FOLLOWING PROPOSAL.

TO MSE Technology Applications, Inc. P.O. Box 4078 Butte, MT 59702 Tel: (406) 494-7248 Fax: (406) 494-7230		PROPOSAL NO. 001-6472-022-I-003/010-B
		DATE OF PROPOSAL December 11, 2001
ATTENTION OF Mike Willis	END USER IWTP (Albany, NY)	YOUR REFERENCE NO.
SHIPPING SCHEDULE	TERMS Progressive – See below	FOB POINT Owosso, MI – Freight Collect

BASIS OF DESIGN

Process Requiring Controls: Industrial Wastewater Process Vents

Location of Control Equipment: Outdoors

No. of Control Stages: One

Stage 1: Packed Tower with Integral Fan

GAS CONDITIONS:	Inlet	Outlet
Flow Rate, ACFM	5640	< 5640
Temperature, °F	85	< 85
Relative Humidity, %	< 100	100
Bulk Gas Composition	Air	Air

CONTAMINANT	INLET	OUTLET	OVERALL REMOVAL EFFICIENCY
SO ₂	75 ppmv	< 5 ppmv	> 94%
H ₂ S	10 ppmv	< 4 ppmv	> 60%

SCRUBBER OPERATING PARAMETERS:

Stage	<u>1</u>
Pressure Drop, iwg	3.0
Evaporation Rate, gph	10 - 20
* Water Make-Up Rate, gph	210
* Overflow Rate, gph	190 - 200
Recirculation Rate, gpm	100
* Chemical Additives	NaOH
% W/W Stock Solution	20
Chemical Addition Rate, gph	6.0

* Scrubber water must be maintained @ pH > 11 for NaOH scrubbing of H₂S to be effective without excessive makeup water/overflow requirements.

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EQUIPMENT SCOPE OF SUPPLY

- A. (1) Packed Bed Scrubber, Stage 1
 Model Number – FW305-45S
 Flow Configuration – Counter-flow
 Construction – Type II White PVC
 Diameter – 45”
 Liquid Distributor - Sprays
 Bed Depth – 5’
 Type of Packing – 2” dia. polypropylene
 Mist Eliminator – 8” bed of 2” dia. polypropylene
 Recirculation Pump – 5 HP
 Recirculation Sump or Tank – Standard sump box
 Overall Height – 16’
 Insulation – 2” polyurethane around sump with 1/8” FRP skin
 Support System – Steel base and fan support posts
- B. (1) Exhaust Fan
 Construction - PVC
 Model Number - 36
 Position – FW style
 Shaft Seal - Provided
 Motor Horsepower - 10
 Arrangement – FW, belt driven
 Electrical – 460v / 3 ph / 60 hz
 Design – 5640 cfm at 6” w.c. Density – 0.075 lb/ft³
 Allowance for External Losses – 3” w.c.
- C. (1) Chemical Feed System
 Caustic Pump – (1)
- D. (1) Lot Instrumentation
 pH Probe/Analyzer – (1) pH probe / (1) pH analyzer (in main panel)
 Freshwater Flowmeter – (1)
 Pressure Gauge – 0-30 psig with guard
 Magnehelic – (1)
 Low Liquid Level Switch – (1)
 Liquid Level Control – (1)
 Solenoid Valve – (2) ½” brass
 Sump Heater/Controller – 4.5 kw with controller and thermowell
- E. (1) Control Panel
 NEMA Rating - 4
 Fused Disconnect - Provided
 Control Voltage Transformer - Provided
 Sump Heater Relay – 460v, 4.5 kw, HOA
 Solenoid Relay – HOA Chem. Pump, (2) HOA makeup water
 pH/ORP/Conductivity Out-of-Range Alarm – pH, light and horn
 Low/High Liquid Level Alarm – Low, light and horn
 Recycle Pump - Chemical Pump Interlock - Provided

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Low Sump Liquid Level - Recycle Pump Interlock - Provided
Low Sump Liquid Level - Sump Heater Interlock - Provided
Fresh Water Solenoid Valve – Recycle Pump Interlock - Provided

PRICE FOR ITEMS A – E.....\$ 33,950.00

SHIPPING SCHEDULE: Drawings 2-4 weeks after receipt of PO, fabrication 5-7 weeks after drawing approval.

Above prices do not include tax. If non-taxable, please forward tax exemption certificate for the ship to address. **NOTE:** Duall's pricing includes only the items specifically listed in our proposal scope of supply.

EQUIPMENT PERFORMANCES: All representations of equipment performance indicate an expected level of treatment efficiency based upon the process conditions provided by others. If specific performance guarantees are required, they can be provided, if specific inlet conditions are guaranteed to be accurate. If required, please contact Duall Division for a written performance guarantee prior to purchase.

STATIC PRESSURE - The external static pressure for the proposed system has been estimated and may vary depending on actual field conditions. Increased costs due to static pressure increase or decrease shall be by customer.

WARRANTY - Standard Duall products carry a 1 year warranty from date of shipment. (Please see Duall Terms and Conditions for warranty details.)

TERMS AND CONDITIONS:

PAYMENT

10% upon issue of order
40% before release for shipment
50% Net 30 Days from date of shipment
Subject to credit approval

Duall Division's standard terms and conditions, a copy of which is included with each proposal, apply to all transactions. All terms are subject to credit approval.

PROPRIETARY INFORMATION - All sketches, drawings, performance calculations, and other design criteria submitted with this proposal and/or engineering submittals are the proprietary property of Duall Division Met-Pro Corporation. They are intended only for use by the buyer as a means of description and clarification for equipment and services offered for sale. These items must not be reproduced nor submitted to other parties for examination without our prior written consent.

Application Code: 030400

Duall Proposal No. 001-6472-022-I-003/010-B

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To insure proper processing, a purchase order resulting from this proposal should **REFERENCE OUR PROPOSAL NUMBER**, and be issued to:

MET-PRO CORPORATION DUALL DIVISION
1550 Industrial Drive
Owosso, MI 48867
Attn: Sales Secretary

Our representative in your area:

Doug Cambell
Cam-Tec

Tel: 801 - 566-6000
Fax: 801 - 566-6177

This proposal was prepared by.....Dale Teeple.

The Basis of Design was prepared by.....Randy Nicolli, Chemical Engineer.

BY Michael R. Sprague, Technical Products &
Western Regional Sales Manager
and Jim Mallery, Regional Sales Manager

MET-PRO CORPORATION/DUALL DIVISION

ACCEPTANCE OF THIS OFFER IS LIMITED TO ITS TERMS INCLUDING ALL OF THE TERMS AND CONDITIONS ATTACHED, WHICH TERMS AND CONDITIONS ARE HEREBY MADE A PART HEREOF.

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I. CLARIFICATIONS AND EXCEPTIONS:

- The control panel ships loose and must be wired by others to external devices.
- The vessels ship with the spray headers factory installed. The packing ships loose for field installation by others.
- These systems use hazardous chemicals and potentially dangerous rotating equipment which must be operated and maintained by experienced, qualified, and trained personnel. During the course of installation, start-up and testing, the responsibility of safety is by the contractor.
- Unless otherwise stated the proposed equipment uses industry standard designs for gas and/or vapor absorption and high efficiency mist removal for typical mist loadings. Some process conditions may create non-typical aerosol emissions that may exceed standard mist eliminator capacity. The effects of corrosive aerosol mist exiting the scrubber outside of the efficiencies stated in this proposal are the responsibility of others. Contact Duall Division for information on aerosol formation and recommendations for utilizing premium efficiency mist elimination techniques.

II. ITEMS NOT SUPPLIED BY DUALL:

- All permits, taxes, duties, brokerage, and licensing fees are the responsibility of others.
- Freight.
- Freight and driver detention expenses.
- All chemicals.
- Off loading and storage.
- All piping, valves, and accessories required to complete installation.
- All electrical wiring, motor control centers, local disconnects, instrumentation, and connection accessories.

OPTIONAL EQUIPMENT: Unless specifically listed in our scope of supply, these items are not part of this proposal. Please contact Duall for optional pricing.

- Spare parts.
- Chemical storage tanks or drums.
- Inlet ducting and collection hoods
- Exhaust stack.
- Gas detectors and or sensors.
- Dampers.
- Pre-wiring or skid mounting.
- Export crating.

OPTIONAL SERVICES: Unless specifically listed in our scope of supply, these items are not part of this proposal. Please contact Duall for optional pricing.

- Installation (basic).
- Start-up and balancing.
- Training.
- Performance testing.
- Annual or biannual system inspection and balancing (site visits).
- Installation supervision.

DUAL DIVISION MET-PRO CORPORATION**MODEL FW300 SERIES FAN-SCRUBBERS**

Duall scrubbers are manufactured from Type II Grade I PVC - conforming to ASTM D1784 and containing no plasticizers, or from polypropylene - conforming to ASTM P2146. All vessels are of hot-gas welded construction and are hydrostatically tested at the factory by filling to the air inlet nozzle.

Structural Design

The structural design is based on operation at a maximum temperature of 120°F, with a 100 mph wind load, and in seismic zone 3. A load safety factor of three (3) is applied to the design. Tie downs, guy wires, anchor bolts, and foundation are not provided by Duall.

Packing

Packing is random-dumped, high-efficiency type. It is fabricated from polypropylene. The packing is factory installed.

Demister

Scrubbers have an integral mist eliminator. This will be 8" of polypropylene packing. The mist eliminator will remove 99% of droplets 20 microns and larger. The packing will be factory installed.

Access

An access doors with clear PVC cover is provided for inspection of the spray nozzles.

Liquid Distribution

The liquid distributor consists of low-pressure spray nozzles in a header arrangement. The maximum nozzle pressure is 10 psig. The entire assembly is constructed from Schedule 80 PVC pipe with PVC nozzles. It is installed at the factory. Hayward full-union PVC ball valves are provided for flow control. External pipe, fittings, valves are not provided by Duall.

Recirculation Pump

Scrubbing solution is recirculated by a Sethco pump with TEFC motor. Each pump and motor will be factory-mounted on a side sump or remote tank. Plumbing, electrical work, local disconnects, heat tracing, and insulation are not provided by Duall.

Exhaust Fan

The fan is integral to the scrubber and is complete with TEFC motor, belt drive, OSHA-approved belt and shaft guards, and flanged inlet and outlet.

Duall Division Met-Pro Corporation certifies that the exhaust fan is licensed to bear the AMCA Seal. Ratings are based on tests made in accordance with AMCA Standard 210 and comply with the requirements of the AMCA Certified Ratings Program.

The fan housing, and guards, are constructed of Type II Grade I PVC, conforming to ASTM D1784-78 containing no plasticizers, or polypropylene, conforming to ASTM P2146-78. All hardware is 316 stainless steel. An undrilled outlet flange is provided; field drilling is not by Duall.

Duall RB and NH fans have steel wheels of Class II construction. RB wheels are radial

blade design. NH wheels are backwardly inclined design. They are coated with corrosion resistant glass-reinforced vinyl ester resin. The wheels are keyed to steel shafts and are statically and dynamically balanced, to a maximum of one mil vibration at design speed, utilizing a Model 206 analyzer from Production Measurements Corporation.

Duall fans have heavy-duty, grease-lubricated, self-aligning, precision, anti-friction pillow block bearings that have a minimum average life (AFBMA L50) of 100,000 hours. Fan shaft is mild steel turned ground and polished, and conforms to AISI 1045.

Duall provides constant-pitch, V-belt drives with 1.5 service factor. Belts are at minimum size "B", high-capacity type and are provided in matched sets.

Motors are high efficiency totally-enclosed, fan-cooled type operating with 460 volt, 3 phase, 60 hertz electrical power. They are NEMA design B and Class F insulated with 1.15 service factor. Motors are mounted on a slide-rail base. Discrete (On/Off), full-speed control is provided. Disconnects, heaters, and electrical protection are not provided by Duall.

Arrangement 9 is provided with the motor factory-mounted on an epoxy-coated steel pedestal.

Outdoor Installation

To maximize protection from freezing weather, we suggest that the equipment be installed indoors. Any heat tracing, tank heaters, insulation, and painting that may be required for outdoor installation are the responsibility of others, and are not provided by Duall.

Connections

Inlet and outlet flanges must be field-drilled by the Contractor. This will prevent alignment problems with mating ductwork.

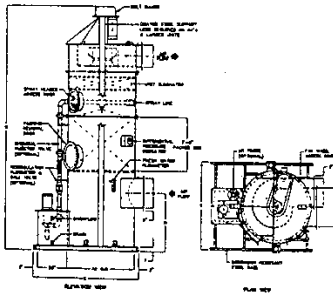
Plumbing connections 1/2" to 4" are threaded couplings, while 6" and larger are 150# ANSI flanges. All couplings and flanges are PVC. Mating flanges, hardware, and gaskets are not provided by Duall.

Features and benefits of Dual Series F, FW and PT Scrubbers

- ✓ P. E. certified for long-term structural integrity
- ✓ Thermoplastic construction for maximum corrosion resistance
- ✓ UV-resistant PVC, polypropylene and polyethylene available for all outdoor installations
- ✓ Hot gas and extrusion welded construction per AWS G1.10 standards
- ✓ Hydrostatically tested at factory
- ✓ Heavy duty, leak resistant, bolt-on doors
- ✓ Full cone spray nozzles
- ✓ PVC or CPVC Schedule 80 piping
- ✓ Full union PVC or CPVC ball valves
- ✓ Sealless vertical pumps (factory mounted)
- ✓ Packing removal door
- ✓ Differential pressure gauge
- ✓ Fresh water flow meter
- ✓ Heavy-duty flanges
- ✓ Heavy-duty scrubber bottom
- ✓ Integral coated steel base
- ✓ Stainless steel hardware

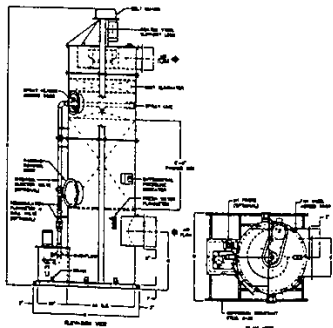
FW303 and FW305 Vertical Fume Scrubbers with Integral Fans and Self-Contained Recirculation Systems

These packed tower-type fume scrubbers are space-savers. They incorporate a rugged built-in fan to eliminate the need for a fan base and connecting duct work between the fan and scrubber. This feature makes the FW303 and FW305 economical models. Standard sizes up to 17,500 CFM are available. Remote circulation systems available.



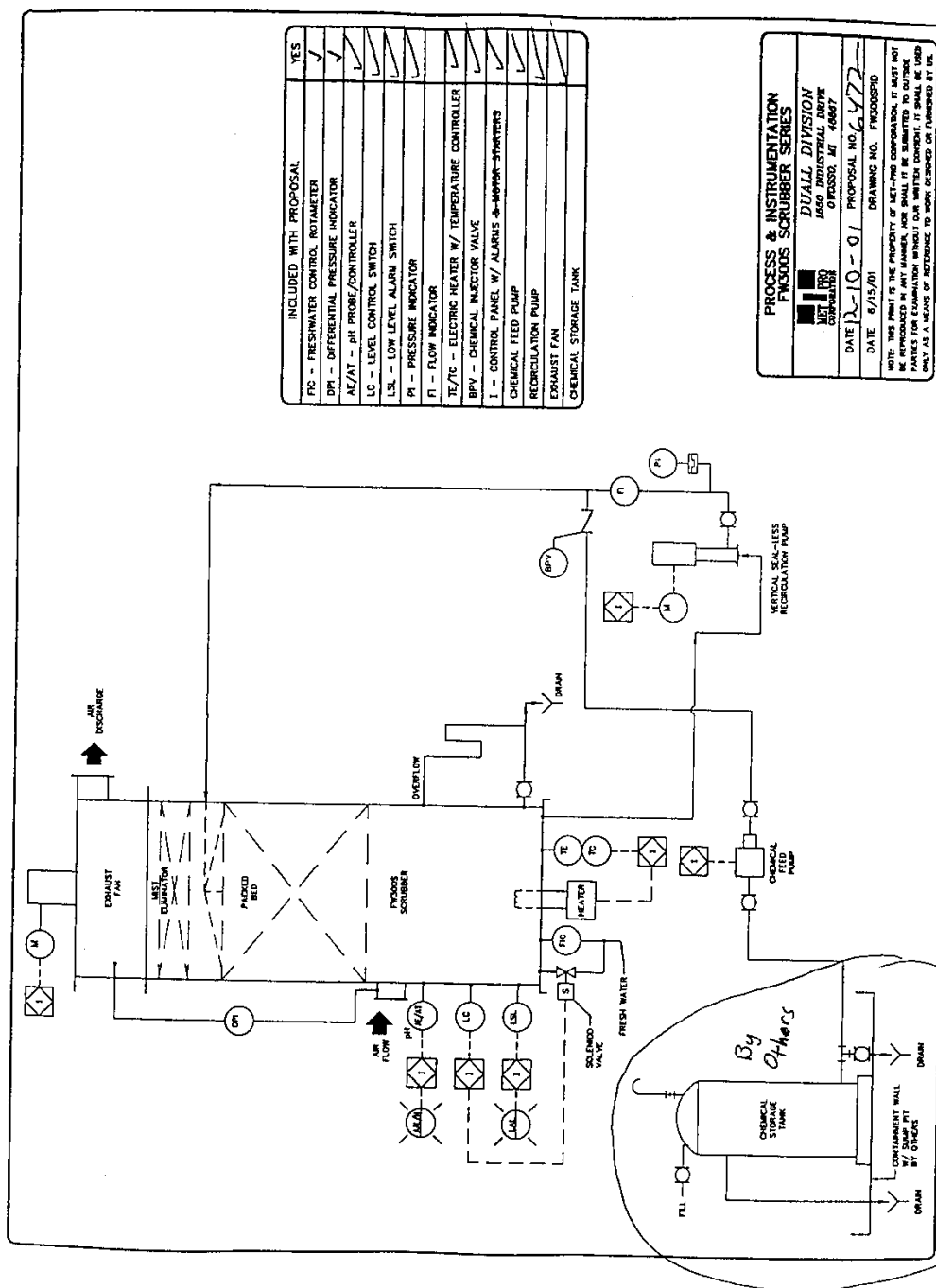
MODEL NUMBER	MAX CFM	A	B	C	D	E	F	G	H	J L.D.	K L.D.	FAN NO.	FAN H.P.	DRY WT.	PUMP QTY. AND H.P.	
FW303-20S	900	20	8 1/2	20	46	3	133	33	5	6 1/2	8	2	687		(1) 1 H.P.	
FW303-26S	1,800	26	10 1/2	26	52	3	138	34	6 1/2	9	8	5	748		(1) 1 H.P.	
FW303-32S	2,800	32	12 1/2	32	58	3	145	35	7 1/2	12	10	7 1/2	801		(1) 2 H.P.	
FW303-34S	3,200	34	15 1/2	34	60	3	153	37	11 1/2	15	30	7 1/2	841		(1) 2 H.P.	
FW303-40S	4,500	40	18 1/2	40	66	3	159	38	13 1/2	17 1/2	33	7 1/2	935		(1) 2 H.P.	
FW303-45S	5,500	45	20 1/2	45	71	3	164	39	14 1/2	19	36	10	1,199		(1) 2 H.P.	
FW303-49S	6,600	49	24 1/2	49	75	3	170	41	17 1/2	23 1/2	44	10	1,271		(1) 2 H.P.	
FW303-53S	7,500	53	24 1/2	53	79	3	174	41	17 1/2	23 1/2	44	15	1,462		(1) 2 H.P.	
FW303-57S	9,000	57	24 1/2	57	83	3	179	41	19 1/2	25 1/2	49	15	1,514		(1) 5 H.P.	
FW303-64S	11,000	64	14	48	78	90	3	170	36	19 1/2	25 1/2	49	15	2,026		(1) 5 H.P.
FW303-70S	13,500	70	16	48	84	96	4	177	36	21 1/2	28 1/2	54	20	2,224		(1) 5 H.P.
FW303-74S	15,000	74	16	52	88	100	4	180	36	23 1/2	31 1/2	60	20	2,246		(1) 5 H.P.
FW303-80S	17,500	80	16	56	94	106	4	187	36	26 1/2	34 1/2	66	25	2,344		(1) 7 1/2 H.P.

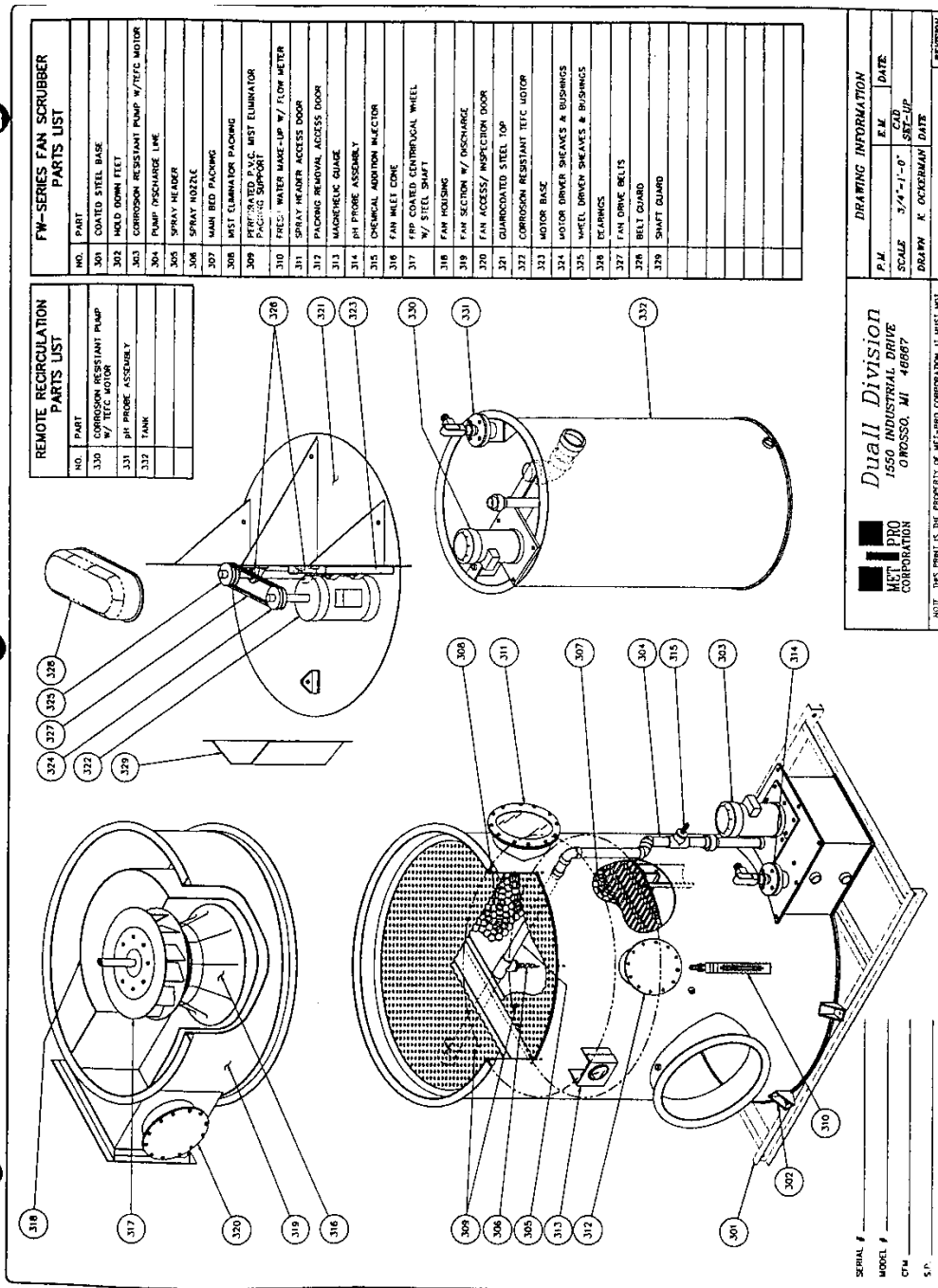
DIMENSIONS IN INCHES



MODEL NUMBER	MAX CFM	A	B	C	D	E	F	G	H	J L.D.	K L.D.	FAN NO.	FAN H.P.	DRY WT.	PUMP QTY. AND H.P.
FW305-20S	900	20	8 1/2	32	46	3	157	33	5	6 1/2	8	3	729	(1) 1 H.P.	
FW305-26S	1,800	26	10 1/2	38	52	3	163	34	6 1/2	9	8	5	790	(1) 1 H.P.	
FW305-32S	2,800	32	12 1/2	44	58	3	169	35	7 1/2	12	10	7 1/2	843	(1) 2 H.P.	
FW305-34S	3,200	34	16 1/2	46	60	3	177	37	11 1/2	15 1/2	30	7 1/2	883	(1) 2 H.P.	
FW305-40S	4,500	40	18 1/2	52	66	3	183	38	13 1/2	17 1/2	33	7 1/2	1,109	(1) 2 H.P.	
FW305-45S	5,500	45	20 1/2	59	71	3	188	39	14 1/2	19	36	10	1,283	(1) 2 H.P.	
FW305-49S	6,600	49	24 1/2	63	75	3	194	41	17 1/2	23 1/2	44	10	1,355	(1) 2 H.P.	
FW305-53S	7,500	53	24 1/2	67	79	3	198	41	17 1/2	23 1/2	44	15	1,548	(1) 2 H.P.	
FW305-57S	9,000	57	24 1/2	71	83	3	203	41	19 1/2	25 1/2	49	15	1,598	(1) 5 H.P.	
FW305-64S	11,000	64	14	48	78	90	3	194	36	19 1/2	25 1/2	49	15	2,152	(1) 5 H.P.
FW305-70S	13,500	70	16	48	84	96	4	201	36	21 1/2	28 1/2	54	20	2,350	(1) 5 H.P.
FW305-74S	15,000	74	16	52	88	100	4	204	36	23 1/2	31 1/2	60	20	2,372	(1) 5 H.P.
FW305-80S	17,500	80	16	56	94	106	4	211	36	26 1/2	34 1/2	66	25	2,470	(1) 7 1/2 H.P.

DIMENSIONS IN INCHES

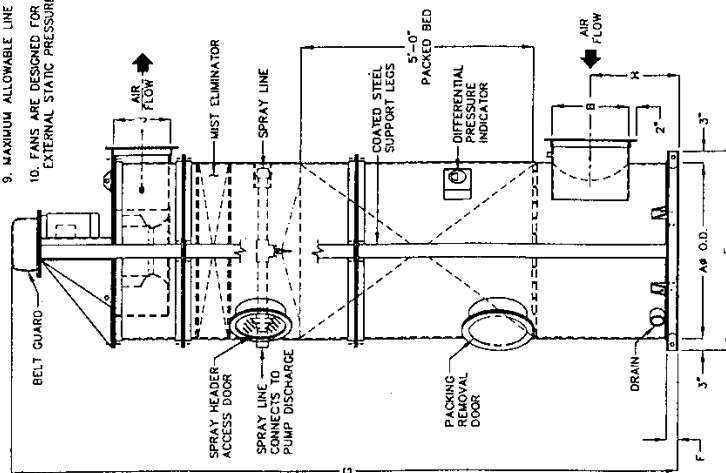




© 1994 MET-PRO CORPORATION

NOTES:

1. DIMENSIONS IN INCHES. WEIGHTS IN POUNDS. 5. LIFTING LUGS ARE SUPPLIED BY DUALL AS REQUIRED.
2. DIMENSIONS ARE APPROXIMATE ONLY. DO NOT USE FOR FABRICATION.
3. STANDARD MATERIALS ARE PVC, CPVC, PP, & PVC/TRP.
4. MAXIMUM PRESSURE DROP ACROSS THE SCRUBBER AT DESIGN CONDITIONS IS 2 1/2" W.C.
6. REMOTE TANK MUST BE LOCATED WITHIN 40'-0" HORIZONTALLY OF THE SCRUBBER.
7. SCRUBBER DRAIN SIZE MUST NOT BE REDUCED.
8. MAXIMUM ALLOWABLE VERTICAL LIFT IS 30'.
9. MAXIMUM ALLOWABLE LINE FRICTION IS 12".
10. FANS ARE DESIGNED FOR UP TO 2" W.C. EXTERNAL STATIC PRESSURE.

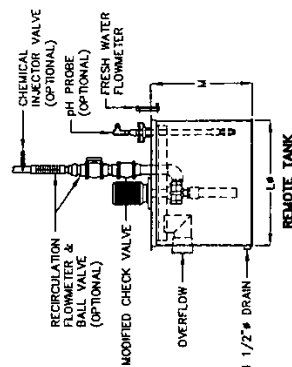


ELEVATION VIEW

CAD NO. FW305RS
DATE: 7/24/00

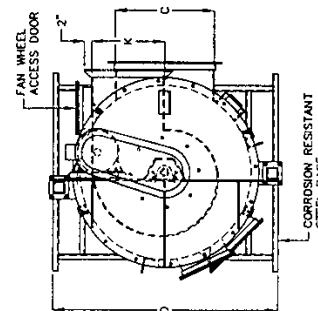
MODEL NUMBER	MAX. CFM	A	B	C	D	E	F	G	H	J ₁	K ₁	L	M	DRAIN & FAN OVERFLOW NO.	FAN H.P.	DRY WEIGHT	PUMP CAP. AND H.P.	
FW305-20R	900	20	8 1/2	32	26	3	139	15	5	3 1/2	30	42	2	2	3	584	(1) 3 H.P.	
FW305-26R	1,800	26	10 1/2	38	32	3	145	16	6	4	30	42	2	8	5	632	(1) 3 H.P.	
FW305-32R	2,800	32	12 1/2	44	38	3	151	17	7	5	30	42	3	10	7	675	(1) 3 H.P.	
FW305-34R	3,200	34	16	46	40	3	159	19	11 1/2	15	30	42	3	30	7 1/2	706	(1) 3 H.P.	
FW305-40R	4,500	40	18 1/2	52	46	3	165	20	13 1/2	17	30	54	3	33	7 1/2	815	(1) 3 H.P.	
FW305-45R	5,500	45	20 1/2	59	51	3	172	23	14 1/2	19	36	66	4	36	10	1,026	(1) 5 H.P.	
FW305-49R	6,600	49	24 1/2	63	55	3	178	25	17 1/2	23	36	66	4	44	10	1,084	(1) 5 H.P.	
FW305-53R	7,500	53	24 1/2	67	59	3	182	25	17 1/2	23	36	66	4	44	15	1,236	(1) 5 H.P.	
FW305-57R	9,000	57	24 1/2	71	63	3	187	25	19 1/2	25	36	66	4	49	15	1,278	(1) 5 H.P.	
FW305-64R	11,000	64	14	48	78	70	3	180	22	19 1/2	25	42	66	6	49	15	1,722	(1) 5 H.P.
FW305-70R	13,500	70	16	48	84	76	4	187	24	21 1/2	28	48	66	6	54	20	1,880	(1) 5 H.P.
FW305-74R	15,000	74	16	52	88	80	4	190	24	23 1/2	31	48	66	6	60	20	1,898	(1) 7 1/2 H.P.
FW305-80R	17,500	80	16	56	94	86	4	197	24	26 1/2	34	54	66	6	66	25	1,976	(1) 7 1/2 H.P.

FAN RPM	STATIC PRESSURE	W.C.
BRAKE HP	V	PH HZ



MODEL FW305 SCRUBBER (REMOTE RECIRCULATION)	
DUALL DIVISION 1000 WEST 17TH AVENUE OAKS, NJ 07439	
DATE	DUALL JOB NO.
AIR FLOW RATE	CFM
PRESSURE DROP	W.C.
RECYCLE RATE	GPM
MAKE-UP RATE	GPH

NOTE: THIS PRINT IS THE PROPERTY OF MET-PRO CORPORATION. IT MUST NOT BE REPRODUCED IN ANY MANNER NOR SHALL IT BE SUBMITTED TO OUTSIDE PARTIES FOR EXAMINATION WITHOUT OUR WRITTEN CONSENT. IT SHALL BE USED ONLY AS A MEANS OF REFERENCE TO MORE DETAILED OR FURNISHED BY US.



PLAN VIEW

PART A

SOLICITATION/CONTRACT/ORDER FOR COMMERCIAL ITEMS		1. SOLICITATION NUMBER 81123G	
PURCHASE ORDER NUMBER		3. AWARD/EFFECTIVE DATE	
OR INFORMATION CALL: William T. Ferko SE Technology Applications, Inc. P.O. Box 4078 Butte, MT 59702		4. SOLICITATION ISSUE DATE 12/18/2001	
PHONE NUMBER: (406) 494-7184		6. OFFER DUE DATE/LOCAL TIME 01/09/2002 12:00 Noon MST	
ISSUED BY SE Technology Applications, Inc. P.O. Box 4078 Butte, MT 59702		9. DELIVERY IS FOB DESTINATION	
DELIVER TO SE Technology Applications, Inc. P.O. Box 4078 Butte, MT 59701		10. DISCOUNT TERMS Progressive Net 30 See attached	
Vendor/OFFEROR Met-Pro Corporation Duall Division 1550 Industrial Drive Owosso, MI 48867 PHONE NUMBER: 989 - 725-8184		12. METHOD OF SOLICITATION Request for Quote	
CHECK IF REMITTANCE ADDRESS IS DIFFERENT AND PUT SUCH ADDRESS IN OFFER		14. PAYMENT WILL BE MADE BY MSE Technology Applications, Inc. Attn: Accounts Payable P.O. Box 4078 Butte, MT 59702	
ITEM NUMBER	16. SCHEDULE OF SUPPLIES/SERVICES	17. QUANTITY	18. UNIT
	WTP S02 Scrubber - Per the specifications contained in PART C SCOPE OF WORK/SPECIFICATIONS	1	EA
			19. UNIT PRICE
			\$33,950.00
			20. AMOUNT
			\$34,800.00 With freight to New York
CHARGE NUMBER		22. TOTAL AWARD AMOUNT (For MSE Use Only)	
SOLICITATION INCORPORATES BY REFERENCE MSE TERMS AND CONDITIONS.			
VENDOR IS REQUIRED TO SIGN THIS DOCUMENT AND RETURN 2 COPIES TO ISSUING OFFICE. VENDOR AGREES TO FURNISH AND DELIVER ALL ITEMS SET FORTH OR OTHERWISE IDENTIFIED ABOVE AND ON ANY ADDITIONAL SHEETS SUBJECT TO THE TERMS AND CONDITIONS SPECIFIED.		25. AWARD OF PURCHASE ORDER; REFERENCE OFFER DATED _____ YOUR OFFER FOR SOLICITATION NO. (See Block 4) INCLUDING ANY ADDITIONS AND CHANGES WHICH ARE SET FORTH HEREIN, IS ACCEPTED AS TO ITEMS.	
SIGNATURE OF OFFEROR / Vendor <i>Michael R. Sprague</i>		27a. SIGNATURE OF Purchasing Agent	
NAME AND TITLE OF SIGNER (Type or Print) Michael R. Sprague Technical and Western Regional Sales Manager		26c. DATE SIGNED 1/2/02	
		27b. Purchasing Agent (Type or Print) William T. Ferko	
		27c. DATE SIGNED	

(End of Part A)

TERMS AND CONDITIONS OF SALE

Following terms and conditions form part of each proposal submitted by Met-Pro Corporation, its officers or subsidiaries, hereinafter called "Seller," for the sale of equipment, machinery, materials, or services (collectively the "Contract Goods") to a Client/Customer, hereinafter called "Buyer." The terms and conditions of the Contract Goods shall be those set forth in the attached "Contract Goods" form, which shall be binding on Seller unless in writing and signed by a representative of Seller duly varied for that purpose. Any contract resulting from this proposal shall be construed and enforced in accordance with the laws of the State of Pennsylvania without giving effect to the choice or non-choice of law provisions or rules thereof. The parties to this contract shall be deemed to have agreed that this contract shall be brought only in the Court of Common Pleas of Montgomery County, Pennsylvania, or the United States District Court for the Eastern District of Pennsylvania, and hereby consent to venue in

SERIAL WARRANTY

Seller's Warranty – Seller warrants to Buyer that the Contract Goods manufactured by it is free from defects in material and workmanship and normal use and service for a period of eighteen (18) months after delivery or twelve (12) months after initial operation, whichever is longer. If the period of time as certified previously is not on the face of the written quotation or order form, there shall be no additional period unless Seller expressly agrees in writing to a longer warranty. All auxiliary equipment not factored by Seller carries such warranty as given by the manufacturer thereof and which is hereby sold to Buyer without recourse to Seller. Seller's warranty for consumables shall be provided over the applicable aforementioned period.

18 - Upon discovery of defects in materials or workmanship during such eighteen (18) months after or twelve (12) months after initial operation as described above, Seller shall either repair or replace the equipment on the condition that the conditions set forth immediately below are met. Even if repair or replaces the equipment, its original warranty term is not extended. Seller's obligation under this warranty is, at Seller's sole option, to a one-time repair or replacement of any part which is not to Seller's reasonable satisfaction to have been defective as to material, workmanship or design, to that:

written notice of such defect is given to Seller within ten (10) calendar days of discovery thereof, the equipment has been installed and operated in accordance with the purpose for which it was purchased and the installation, operating, and maintenance instructions provided by Seller; no alterations or substitutions have been made in the equipment; Seller may require the return of the defective material to establish any claim or make repairs but in no event shall the material be returned without Seller's consent. All returned equipment or parts must be free from any hazardous materials; no payment or allowances will be made for repairs or alterations in the equipment unless Seller's prior written approval has been obtained. All removal, shipping, and reinstallation costs shall be to Buyer's account, and Seller shall not be required to honor any warranty obligation until such time as it shall have been paid in full by Buyer.

WARRANTY

shall defend at its expense any suit or proceeding brought against Buyer based on any claim that the
 ment manufactured by Seller, except for equipment/material manufactured and/or designed to
 s' specifications, infringes any United States patent issued as of the date of the proposal or contract
 ed Buyer gives to Seller immediate notice in writing of the institution of the suit or proceedings and
 s Seller, through its Counsel, to defend the same and gives Seller all needed information, assistance
 uthority to enable Seller to do so.

any equipment or component manufactured by others, Seller shall pass through any patent indemnity as by said manufacturer. Seller's liability shall be limited to rendering reasonable assistance to Buyer under said indemnity, which term shall not be deemed to include the payment of any fees or expenses for legal counsel or to require Seller to institute suit or to participate in any such litigation.

WARRANTIES AND DISCLAIMERS

WARRANTIES FURNISHED BY SELLER AS EXPRESSLY INCLUDED HEREIN
TITUTE SELLER'S SOLE OBLIGATION HEREUNDER AND ARE IN LIEU OF ANY OTHER
LANTIES, EXPRESSED OR IMPLIED, INCLUDING WITHOUT LIMITATION WARRANTIES
FERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE, EVEN IN THE EVENT
FUNDAMENTAL BREACH BY SELLER. THERE ARE NO WARRANTIES, WHICH EXTEND
ND THE DESCRIPTION ON THE FACE HEREOF.

DISCLAIMER OF WARRANTIES

SELLER SHALL NOT BE LIABLE TO BUYER OR BUYER'S CUSTOMER FOR INCIDENTAL, CONSEQUENTIAL OR LIQUIDATED DAMAGES INCLUDING, BUT NOT LIMITED TO, LOSS OF PROFITS, REVENUE, LOSS OF USE OF CONTRACT GOODS, COSTS OF REPLACEMENT GOODS OR CONSTRUCTION OF REPLACEMENT GOODS, LOSS OF USE OF CONTRACT GOODS OR FACILITIES, OR THE CLAIMS OF THIRD PARTIES. EVEN IF SELLER HAS BEEN ADVISED OF POSSIBILITY OF SUCH DAMAGES THIS DISCLAIMER SHALL APPLY TO INCIDENTAL, CONSEQUENTIAL OR LIQUIDATED DAMAGES BASED UPON ANY BREACH OF CONTRACT, ANY BREACH OF WARRANTY, EXPRESSED OR IMPLIED, GUARANTEED, EQUIPMENT OR OTHER CONTRACT GOODS LIABILITY, OR NEGLIGENCE, OR FROM ANY OTHER CAUSE PERTAINING TO PERFORMANCE OR NON-DELIVERY OF, OR TO PROPOSED OR ANTICIPATED CONTRACTS. SELLER SHALL HOLD BUYER HARMLESS FROM ANY SUCH CLAIMS BY BUYER'S CUSTOMER.

SECTION

in receipt of the Contract Goods by Buyer, the same shall not conform to Buyer's orders, Buyer shall return Seller in writing within ten (10) days from receipt of the Contract Goods and before any part of the Contract Goods has been changed from its original condition. Such notification shall provide detailed information as to the nonconformity or shortage and Buyer shall hold the Contract Goods for Seller's inspection and afford Seller a reasonable opportunity to inspect the Contract Goods. Seller may, at its option and without charge, refund the purchase price, or make a fair allowance for defects or shortages if Seller is satisfied to have existed at the time of delivery. Seller may require the return of the Contract Goods to establish any claim but in no event shall Contract Goods be returned without Seller's written consent.

LIMITATION OF LIABILITY OF SELLER

In addition to the other limitations on Seller's liability provided for herein, in no event will Seller's liability to Buyer for any and all claims, including property damage or personal injury claims, allegedly resulting from breach of contract, warranty, strict liability, tort, or any other theory of liability involving this proposal or contract exceed the amount of the purchase price paid to Seller.

PRICE

1. Prices are F.O.B. point of shipment.
2. Oral and written quotations are subject to acceptance within thirty (30) days from date.
3. Prices on equipment of Seller's manufacture are firm, provided it is shipped within the quoted and agreed upon shipment schedule. If Buyer causes shipment to be delayed Seller reserves the right to invoice at Seller's price after time of shipment.
4. Prices on equipment of other manufacturers are subject to cataloger scale of Seller's supplier, if any.
5. Any excise, sales, use taxes or other taxes imposed by Federal, State, or municipal authority and imposed by Seller applicable to the material sold, shall be to Buyer's account and in addition to the prices quoted, unless Buyer provides Seller with a proper tax-exemption certificate. Buyer hereby agrees to indemnify, defend and hold harmless Seller from any taxes, fines, penalties and costs, including attorneys' fees, incurred or paid by Seller arising out of any such claim of exemption. This defense and indemnity requirement shall survive this contract and any releases resulting from same.

TERMS

1. Terms of payment are thirty (30) days NET from date of invoice, no discounts, unless otherwise specified. Seller may invoice on an installment basis where the Contract Goods are so delivered.
2. For late payment, Buyer is subject to a late charge of eight percent (8%) of the unpaid fee per annum (1.3%).
3. If Seller does not receive payment in full for the Contract Goods and any monies otherwise due by the due date then Seller may, at its option at any time while the whole or any part of the monies due remain outstanding, take any action of the Contract Goods as provided in law, without notice to Buyer, and without any agreement, in which case Seller is entitled to recover any loss, including loss of profit, which loss will carry interest under paragraph 2 of this Section.
4. No late payments fees or backcharges will not be accepted by Seller.
5. Buyer will be responsible for all expenses incurred from any collection proceeding.

DELIVERY

- Delivery dates are estimated by Seller on the basis of the best available information and cannot be guaranteed. Where Contract Goods are delivered by multiple deliveries, Seller may deem each delivery to be a separate contract, and no default or failure by Seller in respect of any one or more installments shall vitiate any contract with respect to Contract Goods previously delivered or undelivered.
- 10.1.2.3. **Force Majeure.** Seller shall not be liable for any delay or failure in the delivery of any goods, or for failure to manufacture, or failure of equipment to operate, due to causes arising out of force of law in shipment or delivery, or any other cause beyond Seller's reasonable control, such as, but not limited to, Acts of God, Acts of Buyer, Acts of Civil or Military Authority, priorities, fires, strikes, floods, epidemics, quarantine restrictions, war, riot, delays in transportation, car shortages, and Seller's inability to obtain necessary stock, materials, or manufacturing facilities. In the event of any such delay, the date of delivery shall be extended for a period equal to the delay and Seller shall be entitled to an equitable adjustment in the sales price for increased costs incurred.
- 10.1.2.4. **Loss or Damage.** Contract Goods furnished hereunder shall pass to Buyer, F O B , point of shipment. Seller reserves the right to ship all or any part of the Contract Goods from any shipping point of any of its sources or from other than the source specified in the contract, and the goods may be made by the method or carried down most feasible by Seller unless otherwise requested in writing by Buyer.

GRANT OF SECURITY INTEREST

As security for the payment in full for the Contract Goods, as a condition of the passage of title to Buyer for the Contract Goods as provided for hereunder, Buyer grants to Seller a first priority security interest in the Contract Goods, wherever located, together with all Accounts, Products and Proceeds of any and all of the Contract Goods (as such terms are defined by the Uniform Commercial Code as from time to time in effect in any applicable jurisdiction). Upon default in payment by Buyer, Seller may exercise all rights of a Secured Party as provided for by the Uniform Commercial Code.

CANCELLATION

Cancellation of order by Buyer, or any part thereof, will not be effective unless accepted by Seller in writing. Accepted cancellation will be subject to a charge to cover all costs incurred to the date of acceptance, plus reasonable cancellation costs, plus profit on the completed work.

SUSPENSION

In the event Buyer suspends the execution of work, Buyer shall reimburse Seller for all costs incurred by Seller as a result of such suspension, including, without limitation, all borrowing and opportunity costs. In the event the suspension exceeds 180 days in duration, in addition to being entitled to full reimbursement of costs as aforesaid, Seller shall have the unilateral right to cancel the unfinished portion of the contract without liability to Buyer of any kind.

GENERAL CONDITIONS

1. Non-stock Contract Goods made specifically in order are not subject to return for credit. Any portion of non-stock Contract Goods in process of manufacture is not subject to cancellation. Any charges after manufacture has started could necessitate additional charges for work done and material consumed.
2. Quotations are merely negotiations to trade and not offers to contract.
3. Changes in the right of return of Seller's Contract Goods for electrical and/or thermographic errors or omissions
4. Changes in design are made at Seller's discretion. Seller has no obligation to incorporate these changes in units manufactured prior to the change.
5. It is expressly understood that any and all drawings, instructions, and/or technical and engineering services, which Seller may furnish with reference to the installation or use of its Contract Goods, are furnished solely for the review and approval of Buyer. Seller has no responsibility or warranty with respect to the accuracy or sufficiency of any such information and assumes no obligation or liability for results obtained.
6. Waiver by Seller of a breach of any of these Terms and Conditions shall not be construed as a waiver of any other breach.
7. To combat corrosion, abrasion, or erosion, or operation at elevated temperatures, any such recommendations will be based on the best available experience of Seller and the supplier of the material, BUT WILL NOT CONSTITUTE A GUARANTEE AGAINST THESE EFFECTS.
8. All drawings, patterns, specifications and information included in Seller's proposal or contract, and all other information otherwise supplied by Seller to design, manufacture, erect, operate and maintain the Contract Goods and/or the property and/or the goods of Buyer, shall remain the property of Seller at its request. Buyer shall have no rights in Seller's proprietary and confidential property and shall not disclose such proprietary and confidential property to others or allow others to use such property, except as required for the Buyer to obtain service, maintenance, and installation for the Contract Goods purchased from Seller. This clause shall survive the termination of this contract and be in effect as long as the Buyer has possession of any of the Seller's proprietary or confidential property or information. All said information shall remain the property of Seller, and Buyer shall have the right to use said information only for the use and maintenance of the Contract Goods.

Appendix F: Chemcad Model of The Met Pro Scrubber Bid

Form MSE-135

(Rev. 10-95)

Prepared S. Kujava 2/22/02
Checked
File
Project WVA SO₂ Scrubber
Subject MET PRO Scrubber bid

MSE

MSE Technology Applications, Inc.

P.O. Box 4078

Butte, MT 59702

(406) 494-7100 FAX (406) 494-7230

ChemCad Simulator attached.

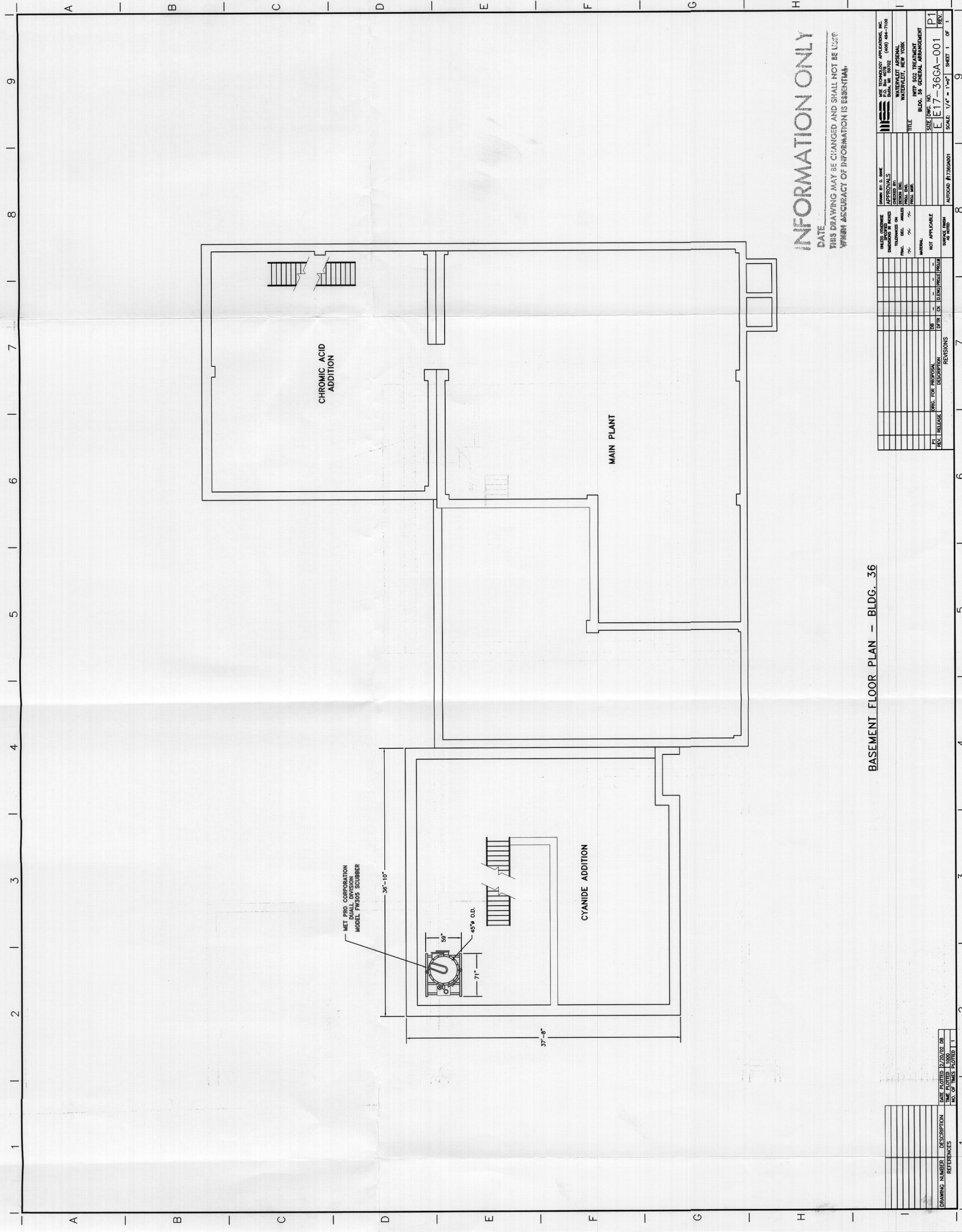
The Duall Division of MET PRO corporation bid was evaluated for conformance to MSE-TA's RFQ and process performance.

A ChemCad Simulation of the proposed process parameters and MSE's specified inlet conditions verified that the proposed scrubber would meet the performance requirements. The proposal states that the scrubber will be packed with six feet of 2 inch polypropylene packing; the simulator assumes that this depth of packing will be equivalent to at least 2 theoretical equilibrium stages.

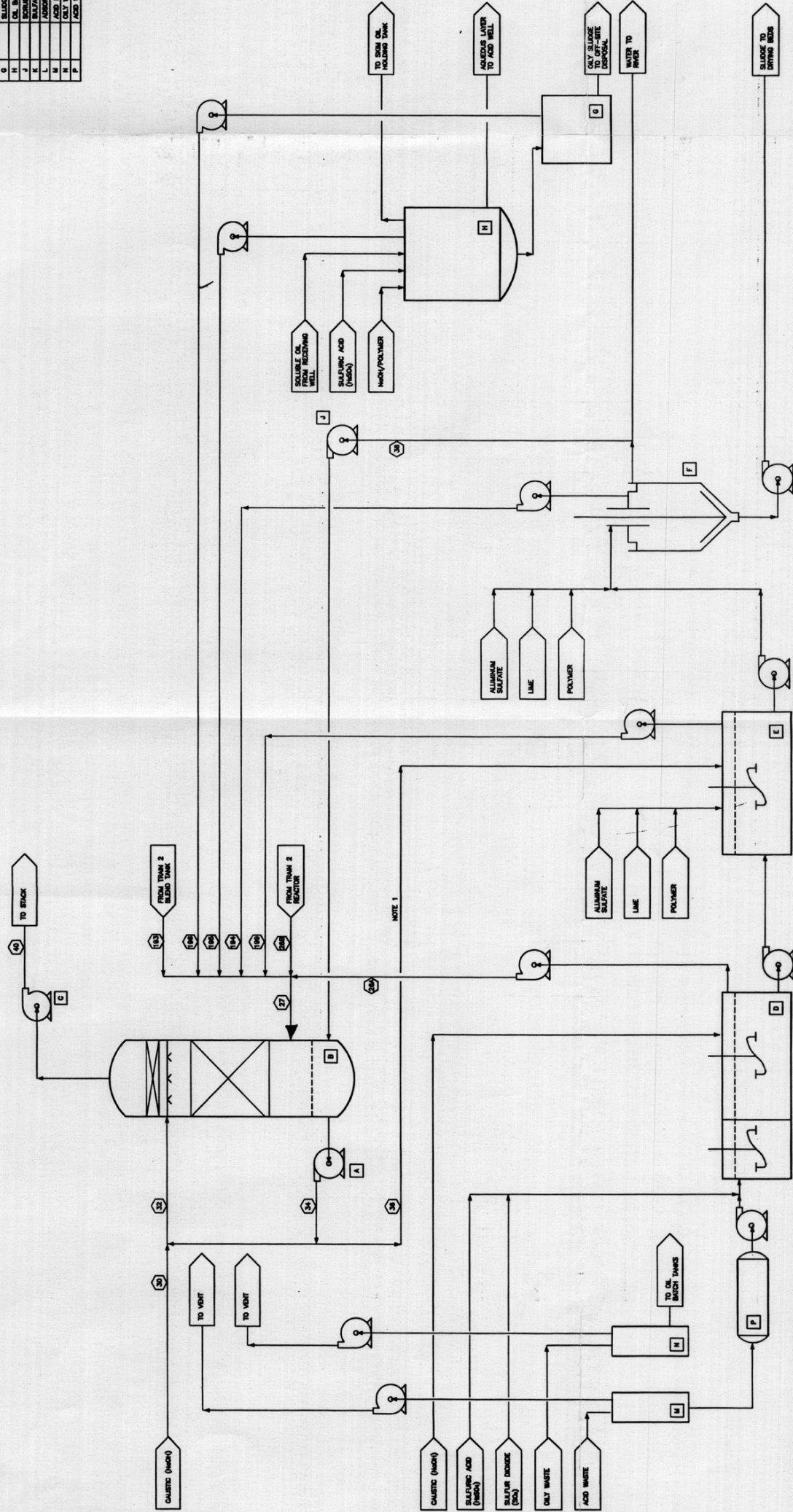
My calculations of 9/10/01 concluded that about 12 feet of packing would be needed. These were based on about half the reflux rate, a lower NaOH input and a less efficient packing material. Given Duall's parameters, I feel their design is adequate.

(This page was transcribed from handwritten notes.)

Appendix G: Process Flow Diagrams



ITEM	ITEM #	DESCRIPTION	REV	REMARKS
A	1	SOLUBLE OIL FROM RECEIVING WELL		
B	2	SOLUBLE OIL FROM RECEIVING WELL		
C	3	SOLUBLE OIL FROM RECEIVING WELL		
D	4	SOLUBLE OIL FROM RECEIVING WELL		
E	5	SOLUBLE OIL FROM RECEIVING WELL		
F	6	SOLUBLE OIL FROM RECEIVING WELL		
G	7	SOLUBLE OIL FROM RECEIVING WELL		
H	8	SOLUBLE OIL FROM RECEIVING WELL		
I	9	SOLUBLE OIL FROM RECEIVING WELL		
J	10	SOLUBLE OIL FROM RECEIVING WELL		
K	11	SOLUBLE OIL FROM RECEIVING WELL		
L	12	SOLUBLE OIL FROM RECEIVING WELL		
M	13	SOLUBLE OIL FROM RECEIVING WELL		
N	14	SOLUBLE OIL FROM RECEIVING WELL		
O	15	SOLUBLE OIL FROM RECEIVING WELL		
P	16	SOLUBLE OIL FROM RECEIVING WELL		



NOTE 1: STREAM 38 CAN OPTIONALLY REPORT TO THE ACID RECEIVING WELL.

INFORMATION ONLY
DATE February 4, 2002
THIS DRAWING MAY BE CHANGED AND SHALL NOT BE USED
WHEN ACCURACY OF INFORMATION IS ESSENTIAL.

STREAM NUMBER	26A	26B	27	30	32	34	36	38	40	193	194	195	196
DESCRIPTION	REACTOR VENT GAS	REACTOR VENT GAS	COMBUSTED VENT GAS	SOLUBILER CHARTIC	SOLUBILER LIQUOR	RECYCLE LIQUOR	SOLUBILER BLOWDOWN	WASH-UP WATER	SOLUBILER OFFGAS	SOLUBILER VENT 2 VENT	194 VENT	195 TANK VENT	196 TANK VENT
FLOW (Lb./Min.)	48.2	44.2	418	0.12	466	528	33.3	35	425	22.2	130	130	22.2
TEMPERATURE (°F)	824	824	8640								1760	1760	300
PRESSURE (PSIA)	88	88	88										
MOISTURE (Lb./Hr)	1.4	1.4	14.8										
MOISTURE (%)	0.074	0.074	0.074							0.074	0.074	0.074	0.074
N ₂	78.3	78.3	78.3										
O ₂	20.8	20.8	20.8										
H ₂ O	0.86	0.86	0.86										
SO ₂ (PPM)	225	225	225										
H ₂ S (PPM)	8	8	8										
CO ₂				0.01	88	83	4.0	4.3					
PM				18.4	11.8	8.1	8.1	7.1					

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ATTN: Topographic Engineering Center, Alexandria, VA

Defense Tech Info Center 22304

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6

6/02

REPORT DOCUMENTATION PAGE				Form Approved OMB No. 0704-0188	
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1. REPORT DATE (DD-MM-YYYY) 06-2002		2. REPORT TYPE Final		3. DATES COVERED (From - To)	
4. TITLE AND SUBTITLE A Preliminary Design of a Ventilation System Scrubber To Reduce Sulfur Dioxide Emissions at the Watervliet Arsenal Industrial Wastewater Treatment Plant				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S) Joyce C. Baird, June Pusich-Lester, and Dan Brown				5d. PROJECT NUMBER Congressional	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER 622720960	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army Engineer Research and Development Center (ERDC) Construction Engineering Research Laboratory (CERL) PO Box 9005 Champaign, IL 61826-9005				8. PERFORMING ORGANIZATION REPORT NUMBER ERDC/CERL TR-02-14	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) Watervliet Arsenal Watervliet, NY 12189				10. SPONSOR/MONITOR'S ACRONYM(S) SOSWV-IMI-E	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.					
13. SUPPLEMENTARY NOTES Copies are available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.					
14. ABSTRACT The intent of this project was to develop a preliminary design of a ventilation system scrubber at the Watervliet Arsenal Industrial Wastewater Treatment Plant to eliminate emissions, which cause nuisance odors.					
15. SUBJECT TERMS emissions control, air pollution control, Watervliet Arsenal, NY, chromium, industrial wastewater treatment plants (IWTPs), sulfur dioxide (SO ₂), hydrogen sulfide (H ₂ S)					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT SAR	18. NUMBER OF PAGES 191	19a. NAME OF RESPONSIBLE PERSON Joyce C. Baird
a. REPORT Unclassified	b. ABSTRACT Unclassified	c. THIS PAGE Unclassified			19b. TELEPHONE NUMBER (in- clude area code) (217)373-4469